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PROCEEDINGS OF THE
 43rd INTERNATIONAL SYMPOSIUM ON
 AGRICULTURAL ENGINEERING

Actual Tasks on Agricultural Engineering



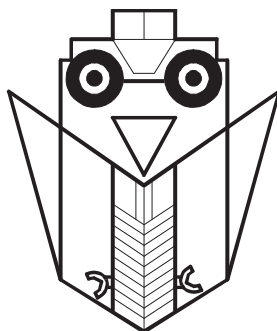
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SVEUČILIŠTE U ZAGREBU AGRONOMSKI FAKULTET
ZAVOD ZA MEHANIZACIJU POLJOPRIVREDE
POLJOPRIVREDNI FAKULTET SVEUČILIŠTA U OSIJEKU
UNIVERZA V MARIBORU FAKULTETA ZA KMETIJSTVO IN
BIOSISTEMSKE VEDE
KMETIJSKI INŠTITUT SLOVENIJE
MAĐARSKI INSTITUT ZA POLJOPRIVREDNU TEHNIKU
HRVATSKA UDRUGA ZA POLJOPRIVREDNU TEHNIKU



AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE



ZBORNIK RADOVA

43. MEĐUNARODNOG SIMPOZIJA IZ PODRUČJA
MEHANIZACIJE POLJOPRIVREDE

OPATIJA, 24. – 27. veljače 2015.

Izdavači <i>Published by</i>	Sveučilište u Zagrebu, Agronomski fakultet, Zavod za mehanizaciju poljoprivrede, Svetošimunska 25, 10000 Zagreb HINUS, Miramarska 13 b, Zagreb
Glavni i odgovorni urednik <i>Chief editor</i>	Igor Kovačev e-mail: ikovacev@agr.hr
Tehnički urednik <i>Technical editor</i>	Hrvoje Zrnčić
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ISSN 1848-4425

<http://atae.agr.hr>

Slika s naslovnice korištena je dobrotom dr. sc. Viktora Jejčića, sina pok. autora Dušana Jejčića

Cover painting is printed by courtesy of dr. sc. Viktor Jejčić, son of late author Dušan Jejčić
Oblikovanje naslovnice / Cover design: Marko Košutić

Svi radovi u Zborniku su recenzirani.

All papers in Proceedings are peer reviewed.

Radovi u Zborniku su indeksirani u bazama podataka od 1997.

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Thomson Reuters: Conference Proceedings Citation Index and ISTP,
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PRIČA O TRAKTORU S NASLOVNICE

SVOBODA DK 12

Zanimljivo područje povijesti traktorske tehnike predstavljaju vrlo jednostavni traktori, manjih snaga, opremljeni uglavnom jednocilindričnim motorima, namijenjeni radu na manjim gospodarstvima krajem dvadesetih i početkom tridesetih godina prošlog stoljeća. Takve traktore je u ponudi imalo nekoliko europskih proizvođača, među kojima su bili i češki traktori Svoboda.

Model Svoboda DK 12, predstavljen na naslovnici, potječe iz 1939. godine. Sličnu koncepciju traktora imali su i drugi proizvođači u početku razvoja, npr. njemački Fendt i Kramer, austrijski Lindner, te legendarni traktori poput američkog Waterloo Boy-a iz 1917. i engleskog Ivel-a iz 1903. godine (izvedba s tri kotača). Spomenuti traktori bili su zasnovani tako da je motor, u osnovi namijenjen za pogon stacionarnih strojeva, pričvršćen na čelični nosivi okvir. Motor je bio vezan s jednostavnim mjenjačem, dodan je rezervoar za gorivo, sjedalo za vozača, sustav za upravljanje i kočenje i tako je nastao vrlo jednostavan traktor.

Trtka Svoboda motor osnovana je 1912. godine u Mladi Boleslavi u Češkoj (tada Čehoslovačkoj). Osnivač je bio Vaclav Svoboda, nakon što je napustio proizvođača automobila Laurin i Klement. Svoboda motor započeo je s proizvodnjom stacionarnog dvotaktnog motora po američkoj licenci, da bi se 1926. Vaclav Svoboda u potpunosti osamostalio i proizvodio različite poljoprivredne strojeve, a 1934. predstavio prvi traktor, Svoboda Diesel, na gospodarskoj izložbi u Pragu. Bio je to jednostavan traktor s tri kotača namijenjen gospodarstvima s malim obradivim površinama. Traktor oznake Svoboda DK 5 imao je jednocilindrični dizel motor s pretkomorom za ubrizgavanje goriva, snage 5 KS (kasnija izvedba snage 7 KM nosila je oznaku DK 7). Motor je bio samo s četiri vijka pričvršćen na okvir od profiliranog čelika. Hlađenje motora bilo je izvedeno na najjednostavniji način, otvorenim sustavom isparavanjem vode (sličan sustav hlađenja imale su i neke izvedbe stacionarnih motora Deutz, Torpedo, itd.). Pogonsko gorivo bilo je plinsko ulje, petrolej i sl. Motor je bio opremljen karakterističnim velikim zamašnjakom, uočljivim na desnoj strani motora. Na zamašnjak je bila pričvršćena remenica za pogon različitih stacionarnih strojeva, npr. vršalica, pumpi za vodu, pila itd.

Kasnije se pojavila i izvedba traktora s četiri kotača (opremljenog pneumaticima) oznake DK 10. Cijena takvog traktora bila je jednaka cijeni para konja. Osnovna izvedba traktora za poljoprivredu bila je najjednostavnije konstrukcije s čeličnim kotačima, bez električne instalacije. Nešto sofisticiraniji model imao je pneumatike, a onaj najbolji i električnu instalaciju (dinamo je je dobivao pogon od motora preko remena). Pored para prednjih svjetala za rad noću, imao je i stražnja pozicijska svjetla, te grijač za lakše pokretanje motora. Prijenos snage od motora do mjenjača bio je riješen pomoću klinastih

remena. Opisani tip DK 10 osuvremenjen je 1939. godine, ugrađen je snažniji dizel motor s 12 KS (oznaka DK 12) i taj je tip bio u proizvodnji cijelih deset godina, sve do 1949. Motor je razvijao 12 KS pri 1000 o/min., a za lakše pokretanje bio je opremljen dekompresorom. Traktor je imao dva stupnja prijenosa za vožnju naprijed i jedan nazad, maksimalna brzina bila je 12 km/h. Kao dodatnu opremu bilo je moguće odabrati Bosch-ovu električnu instalaciju, blokadu diferencijala, čelične kotače, stražnje blatobrane, itd.

Početak četrdesetih godina prošlog stoljeća pojavio se i model DK 22 s dvocilindričnim motorom Deutz F2M414 snage 22 KS. Taj je traktor oblikom već nalikovao standardnim univerzalnim traktorima toga vremena. Slijedila je ugradnja motora Svoboda 25G, pogonjenog generatorskim plinom (znakovito za traktore u doba Drugog svjetskog rata u većini europskih država). Godine 1945. započela je proizvodnja modela DK 15, snage motora 15 KS koji se u proizvodnom programu zadržao do 1949. godine. Svoboda motor je nacionaliziran početkom 1948., da bi naredne godine bio združen s češkom tvrtkom Automobilove zavody narodni podnik, i proizvodnja traktora je, na žalost, prekinuta. Time je okončana i relativno kratka, ali plodna povijest traktora Svoboda. Tko zna kakve bi još izvedbe traktora razvili, ukoliko proizvodnja ne bi bila tako brzo ugašena.

Tekst: Viktor Jejčić

Slika u tehnici akrila: Dušan Jejčić

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Poštovani kolege i čitatelji,

Sustavnim radom malog organizacijskog tima, uz svesrdnu podršku, kako domaćih, tako i kolega iz regije i svijeta, pred nama je Zbornik radova 43. Simpozija „Aktualni zadaci mehanizacije poljoprivrede“. Nedavnim prelaskom na elektroničko-web izdanje možda je izgubljen dio osjećaja zadovoljstva što ga pruža listanje stranica, no Zbornik je postao dostupan širem broju čitatelja što je primarna svrha ovakve publikacije. Pristup web izdanju je besplatan na adresi <http://atae.agr.hr/proceedings.htm> od 30. ožujka tekuće godine. Ovogodišnji 43. Zbornik s ukupno 82 rada jedan je od najopsežnijih u bogatoj povijesti Simpozija, za što je nesumnjivo, svojim neumornim radom i promicanjem ideje ovog skupa, zaslužan dugogodišnji glavni urednik prof. dr. sc. Silvio Košutić kao i njegovi prethodnici. Jednakom predanošću i profesionalnošću tehnički urednik mr. sc. Hrvoje Zrnčić već 14 godina organizatoru olakšava rad i oplemenjuje Zbornik dajući mu prepoznatljivo obličje. Izdavači se nadaju da će Vam aktualno izdanje donijeti dovoljno interesantnih članaka, među kojima se nalaze po jedan (1) rad iz Austrije, Češke i Turske, tri (3) rada iz Litve, pet (5) radova iz Slovenije, po sedam (7) radova iz Hrvatske i Srbije, dvanaest (12) radova iz Italije i četrdeset i pet (45) radova iz Rumunjske. Zahvaljujemo svim autorima, sponzorima i kolegama mehanizatorima koji su svojom potporom omogućili održavanje ovakvog skupa. Posebno se zahvaljujemo Ministarstvu znanosti, obrazovanja i sporta Republike Hrvatske na stalnoj potpori. Svim učesnicima želimo ugodan boravak u Opatiji za vrijeme održavanja Simpozija.

Dear colleagues and readers,

Continuous work of a small organising team, with support, both domestic and colleagues from abroad, yielded with the Proceedings of the 43rd Symposium "Actual Tasks on Agricultural Engineering". Recent transition to electronic web-edition might decreased a sense of satisfaction as it provided by flipping of pages, but the Proceedings becomes available to a wider range of readers as the primary purpose of such publication. Access to the web edition is free at site <http://atae.agr.hr/proceedings.htm> from March 30th of the current year. This 43rd Proceedings, containing 82 papers, is one of the most comprehensive in the rich history of the Symposium, which is undoubtedly a merit of relentless work of long-time chief editor prof. dr. sc. Silvio Košutić along with his predecessors in promoting the idea of this meeting. With his devotion and professionalism technical editor mr. sc. Hrvoje Zrnčić facilitates the organisers' work and refines the Proceedings giving it a distinctive form. Publishers hope that the latest issue brings You enough interesting articles,

among which there are per one (1) paper from Austria, Czech Republic and Turkey, three (3) papers from Lithuania, five (5) papers from Slovenia, seven (7) papers from Croatia and Serbia each, twelve (12) papers from Italy and forty-five (45) papers from Romania. Organiser is grateful to all the authors, sponsors and colleagues that enable this meeting possible. We especially thank the Ministry of Science, Education and Sports of the Republic of Croatia for its continuous sponsorship. We wish all participants a pleasant stay in Opatija during the Symposium.

Chief Editor

Dr. sc. Igor Kovačev

Zagreb, siječanj-January 2015

SADRŽAJ – CONTENTS

R. Halbac-Cotoara-Zamfir	19
Povijest dreniranja tla u poljoprivredi <i>A history of agricultural land drainage</i>	
N. Ungureanu, St. Croitoru, S. Biris, Gh. Voicu, V. Vladut, K.C. Selvi, S. Boruz, E. Marin, M. Matache, D. Manea, G. Constantin, M. Ionescu	31
Zbijanje tla djelovanjem poljoprivrednih strojeva <i>Agricultural soil compaction under the action of agricultural machinery</i>	
L. Masilionyte, S. Maiksteniene	43
Utjecaj agrotehničkih mjera-postupaka na fizikalna svojstva tla u alternativnoj proizvodnji <i>Influence of agro-measures on soil physical parameters in alternative farming</i>	
R. Halbac-Cotoara-Zamfir	55
Analiza suše glavnih poljoprivrednih područja Rumunjske sa SPI i RDI indikatorima <i>An analysis of drought in main agricultural areas from Romania using SPI and RDI indicators</i>	
M. Jančić	67
Utjecaj klimatskih promjena na urod i potrebe navodnjavanja u proizvodnji kukuruza optimiranjem navodnjavanja <i>Climate change impact on yield and irrigation demand in maize production under optimum irrigation method including CO₂ fertilisation effect</i>	
G. Lorenzini, M. Medici, O. Saro, D. De Wrachien.....	77
Protok rasprskivača: procjena klasične i kvantne termičke dinamike fluida <i>Sprinkler jet flow: classical and quantum thermal-fluid dynamical assessment</i>	
N. F. Boja, F. C. Boja, A. C. Teusdea, S. T. Bungescu, I. Popescu	89
Metoda poboljšanja ujednačenosti navodnjavanja rasprskivačima u šumarskim rasadnicima <i>A method to improve the sprinkler irrigation uniformity in forest nurseries</i>	
T. Poje.....	101
Stanje na području kmetijskih traktorjev v Sloveniji <i>Situation in the field of agricultural tractors in Slovenia</i>	

V. Cerović, Z. Mileusnić, D. V. Petrović.....	111
Teoretske granice područja stabilnosti gibanja traktora na nagibu <i>Theoretical limits of the angular stability range of the tractor moving over inclined terrain</i>	
C. Persu, M. Matache, V. Vladut, S. Biris, D. Cujbescu, G. Paraschiv, I. Voicea, B. Ivancu, Gh. Ivan	123
Provjera mehaničke čvrstoće zaštitne strukture rukovatelja traktora <i>Checking the mechanical resistance of an operator protection structures</i>	
M. Matache, Gh. Voicu, P. Cardei, V. Vladut, C. Persu, I. Voicea	131
Ubrzani test okvira podrivača MAS 65 <i>Accelerated test of MAS 65 deep soil loosening machine frame</i>	
V. Vladut, S. Biris, S. Bungescu, N. Faur, A. Cernescu, P. Cardei, M. Matache, O. Kabas, G. Paraschiv, At. Atanasov, Gh. Ivan	141
Provjera naprezanja vučne grede traktora metodom konačnih elemenata i mehaničkim testiranjem <i>The verification of stress by FEM analysis / mechanical testing of a tractor bar</i>	
L. Vladutoiu, V. Vladut, I. Voiculescu, M. Matache, O. Radu, S. Biris, I. Voicea, G. Paraschiv, At. Atanasov, M. Usenko.....	153
Povećanje trajnosti aktivnih dijelova poljoprivrednih strojeva kaljenjem <i>Increasing agricultural machinery active parts durability by hardening</i>	
St. Croitoru, E. Marin, M. Badescu, V. Vladut, N. Ungureanu, D. Manea, S. Boruz, Gh. Matei	165
Agrotehničke i energetske značajke nove konstrukcije podrivača <i>Agrotechnical and energetic characteristics of new designed subsoiler</i>	
S. St. Biris, S. T. Bungescu, D. Manea, N. Boja, T. F. Cilan, R. Martin	177
Novi pristup konstrukciji vibracijskih oruđa za obradu tla <i>State of art approach to vibro-combinators soil tillage implements construction</i>	
S. Biris, V. Vladut, N. Faur, A. Cernescu, M. Matache, O. Kabas, I. Voicea, S. Bungescu, C. Popescu.....	189
FEM analiza / ispitivanje čvrstoće traktorskog sjedala <i>FEM analysis / testing resistance of a tractor seat</i>	
H. A. Petrescu, R. Martin, D. Vlasceanu, A. Hadar, I. Parausanu, R. Dan.....	201
FEM modalna analiza tri aktivna elementa poljoprivrednog stroja <i>Modal analysis using FEM of three active elements for an agricultural machine</i>	
P. Cardei, L. Rigon, V. M. Muraru, C. Muraru-Ionel, N. Constantin, A. David.....	211
Metoda izračuna optimalne brzine kretanja vibracijskog kultivatora <i>A method of calculating the optimal speed of operation for vibro-cultivators</i>	

Z. Mileusnić, R. Miodragović, A. Dimitrijević, V. Cerović.....	223
Analiza energetske značajke agregata traktor-rovilo <i>The energy parameters of the tractor-chisel plough</i>	
E. Sarauskis, K. Vaitauskiene, V. Naujokiene, I. Skukauskaitė, K. Romaneckas, Z. Kriauciuniene, V. Butkus	231
Biotretiranje žetvenih ostataka s ciljem boljeg unošenja u tlo <i>Harvest residues bio-treatment as a soil incorporation improvement</i>	
D. Stajanko, M. Lakota, P. Vindiš	243
Utjecaj načina obrade, temperature i oborina na emisiju CO ₂ iz tla <i>The effect of tillage techniques, temperature and precipitation on CO₂ emissions from light soil</i>	
P. Vindiš, D. Stajanko, M. Lakota	253
Vpliv različitih načina obrade tal na ekološki odtis pri ozimi pšenici <i>Effect of different tillage methods on ecological footprint of winter wheat</i>	
M. Grubor, I. Maletić, J. Lakić, I. Kovačev, S. Košutić.....	265
Ekonomičnost proizvodnje pšenice i uljane repice s različitim sustavima obrade tla <i>Economic efficiency of winter wheat and oil seed rape production in different soil tillage systems</i>	
M. Rosu (Nitu), T. Casandroi, M. Matache, V. Vladut, P. Cardei, S. Bungescu	275
Utjecaj veličine kuta mlaznice na kvalitetu prskanja <i>Influence of the jet's angle size on the spraying process</i>	
Đ. Banaj, V. Tadić, D. Petrović, D. Knežević, Ž. Banaj, G. Heffer	287
Ispitivanje strojeva i opreme za zaštitu bilja u Republici Hrvatskoj <i>Testing technical systems in plant protection in Republic of Croatia</i>	
Z. Kriauciuniene, R. Velicka, A. Marcinkeviciene, R. Pupaliene, L. M. Butkeviciene, R. Kosteckas, S. Cekanauskas	295
Mehaničko i termičko suzbijanje korova i primjena biotretiranja u proizvodnji uljane repice <i>Mechanical and thermal weed control and use of bio-preparations in winter oilseed rape</i>	
D. Cujbescu, Gh. Bolintineanu, E. Marin, V. Vladut, D. Manea, C. Persu, Gh. Voicu, S. Bungescu	307
Usporedba preciznosti sjetvenih uređaja jednosjemenih sijačica <i>Comparative study regarding precision of sowing devices distribution</i>	
B. Ogrizović.....	319
Rezultati setve kukuruza Twin-Row sejalicom u regionu Sombora <i>Results of corn sowing by using twin-row planter in Sombor region</i>	

D. Manea, E. Marin, G. Paraschiv, Gh. Voicu.....	331
Ispitivanje eksperimentalnog modela sijačice za regeneraciju travnjaka <i>Testing experimental model of drill for grasslands regeneration</i>	
L. Popa, E. Marin, A. Nedelcu, R. Ciuperca, V. Stefan, A. Petcu, G. Lazar, A. Zaica	343
Ispitivanje eksperimentalnog modela vučene kosilice-žetelice <i>Testing experimental model of trailed windrower</i>	
G. Fabijanić, I. Kovačev, K. Čopec.....	353
Trendovi razvoja preša za valjkaste bale <i>Recent development of round balers</i>	
A. Muscalu, A. Pruteanu, L. David.....	365
Kvaliteta mehaničkog ubiranja cvata kamilice <i>Quality of mechanical harvesting of chamomile inflorescences</i>	
S. R. Barač, D. V. Petrović, R. L. Radojević, M. O. Biberdžić, A. B. Đikić.....	377
Usporedba samokretnih krmnih kombajna u žetvi kukuruza <i>Comparison of self propelled forage harvesters in maize harvesting</i>	
Gh. Sima, D. Glavan, A. Popa, D. Mortoiu	387
Visoka preciznost proizvodnje s korekcijom u stvarnom vremenu <i>High precision with real time correction in manufacturing</i>	
Gh. Voicu, G. A. Constantin, B. Plosceanu, E. M. Stefan, P. Voicu, D. Stoica.....	395
Analiza vibracijskih pomaka ravnih sita u mlinovima <i>Vibratory movement analysis of plansifters from milling plants</i>	
T. Casandroi, V. G. Ciobanu, A. Paun	405
Matematički model gibanja sjemenki tijekom separacije <i>Mathematical models for describing the seeds motion in separation processes</i>	
Gh. Ivan, V. Vladut	417
Intenziviranje protresivanja na konvencionalnom žitnim kombajnama <i>The intensification of shaking process on the conventional combine harvesters</i>	
Gh. Ivan, V. Vladut, I. Ganea-Christu	431
Poboljšanje dobave na vršidbenom sustavu konvencionalnih žitnih kombajna <i>Improving threshing system feeding of conventional combine harvesters</i>	
D. Statuto, G. Cillis, P. Picuno.....	441
Povijesna kartografija i GIS alati za analizu korištenja zemljišta i krajobraznih promjena <i>Historical cartography and GIS tools for the analysis of land use and landscape changes</i>	

A. Dimitrijević, D. Statuto, C. Sica, O. Ponjičan	451
Mogućnosti korištenja prostorne analize (GIS) kao alata za ulazne podatke u modelu podrške odlučivanju u staklenicima	
<i>Possibilities of using spatial analysis (GIS) as an input data tool for the greenhouse decision support model</i>	
G. Ipate, Gh. Voicu, E. M. Stefan, D. Manea, M. Dinca	461
Nadzor razine prašine u staklenicima pomoću Arduino računala	
<i>Air dust particles monitoring in a greenhouse based on the Arduino</i>	
M. Vizzari, M. Sigura, S. Antognelli.....	473
Procjena ekosustava potreba opskrbe i proračuna putem urbano-ruralno-prirodnog gradijenta	
<i>Ecosystem services demand, supply and budget along the urban-rural-natural gradient</i>	
L. Gaceu, R. Gruia, D. Mnerie	485
Model simulacije energije agroekosustava – primjer studije stočarske farme	
<i>Energy simulation model of agroecosystem – case study of animal breeding farm</i>	
G. A. Constantin, Gh. Voicu, V. Tudose, G. Paraschiv, B. Ivancu.....	495
Analiza sustava ovjesa ravnih sita u mlinovima	
<i>Analysis of suspending system for plansifters from milling plants</i>	
B. Ivancu, Gh. Voicu, A. Paun, V. Vladut, G. A. Constantin, F. Ilie.....	505
Harmonička analiza vibracijske dobave s modulom “linearne dinamike”	
<i>Harmonic analysis of a vibrating feeder using “Linear dynamics” module</i>	
M. Ionescu, Gh. Voicu, S. St. Biris, N. Ungureanu, V. Vladut, I. Voicea, C. Persu	513
Tiješnjenje ulja vijčanom prešom s mrežastim izlaznim cjedilom	
<i>Oil expression process using screw presses with strainers oil outlet</i>	
D. Stoica, Gh. Voicu, V. Moise, G. A. Constantin, C. Carp-Ciocardia	525
Kinematička-strukturna analiza pogonskog mehanizma stožastog sita s oscilirajućim kretanjem	
<i>Kinematic-structural analysis of actuating mechanism of a conical sieve with oscillating movement</i>	
L. Gaceu, D. Mnerie, O. B. Oprea, G. Mnerie	537
Nadzor procesa sušenja biljnih proizvoda s infracrvenom fotografijom	
<i>Monitoring the drying process of vegetal products by using infrared images</i>	
I. David, C. Mișcă, C. Costescu, A. Velciov.....	547
Biokatalitički utjecaj lipaze na različite tipove brašna	
<i>The biocatalytic impact of lipase on different types of flour</i>	

E. Lengyel, L. Oprean, L. Rosca, M. Tita, M. Ognean, O. Tita	557
Identifikacija vinskih kvasaca <i>saccheromyces cerevisiae</i> izoliranih iz domaćeg izvora <i>Identification of saccheromyces cerevisiae wine yeasts isolated from local area</i>	
I. D. Mironescu, M. Mironescu.....	563
Ekspertni sustav nadzora-upravljanja biorazgradnje škroba <i>Expert system based control of the starch bioconversion process</i>	
I. D. Mironescu	573
Petri Net model ishrane šećerne repe (<i>Beta vulgaris</i>) u integralnoj proizvodnji <i>Petri net based model of sugar beet (Beta vulgaris) nutrition for integrated sugar production management</i>	
D. I. Stegarus.....	583
Vrednovanje koncentracija metala rumunjskih vina pomoću grafitne peći AAS <i>Evaluation of metals concentrations in Romanian wines by graphite furnace AAS</i>	
C. Sorica, I. Pirna, M. Matache, E. Sorica, C. Bracacescu, D. Manea, I. Dutu.....	589
Utvrđivanje kvalitativnih pokazatelja UV-C uređaja na smanjenje broja mikroorganizama na površini hortikulturnih proizvoda <i>Determination of the qualitative indices of an UV-C installation for microbial reduction on the exterior of horticultural products</i>	
A. Bauer, J. Lizasoain, O. Pavliska, J. Gittinger, M. Saylor, I. Kral, G. Piringer, A. Gronauer	599
Potencijali anaerobne digestije poljoprivrednih nusproizvoda – nove tehnologije <i>Agricultural residues for anaerobic digestion: technologies to open up new resources</i>	
T. Poje.....	617
Bioplinke naprave v Sloveniji – problemi in priložnosti <i>Biogas plants in Slovenia – problems and opportunities</i>	
N. Bilandžija, M. Kontek, N. Voća, T. Krička, J. Leto, S. Sito, A. Matin, V. Jurišić	625
<i>Sida hermaphrodita</i> kao kultura za proizvodnju energije <i>Sida hermaphrodita as energetic plant</i>	
D. Djatkov, M. Viskovic, J. Rajcetic, M. Golub, M. Martinov	635
Istraživanje mogućnosti proizvodnje biometana iz kukuruzovine u Vojvodini <i>Investigation on possibilities of biomethane production from corn stover in Vojvodina</i>	
G. Moiceanu, Gh. Voicu, G. Paraschiv, M. Dinca, M. Ferdes, M. Chitoiu, G. A. Constantin, G. Musuroi	645
Utrošak energije u StL sustavu temeljenom na biomasi <i>Energy consumption to the formation of solid-liquid system based on vegetal biomass</i>	

M. Dinca, Gh. Voicu, G. Paraschiv, M. Ferdes, G. Moiceanu, P. Voicu, M. E. Stefan	657
Anaerobna digestija biljne biomase u proizvodnji bioplina <i>Anaerobic digestion of vegetal biomass used for biogas production</i>	
I. Voicea, V. Vladut, P. Cardei, M. Matache, I. Gageanu, Gh. Voicu, C. Popescu, G. Paraschiv, O. Kabas	667
Matematički model ekspanzije briketa miscanthusa nakon prešanja <i>Compacting process and mathematical analysis of miscanthus briquettes expansion</i>	
R. Polat, H. Oguz, T. Aktas, A. E. Erdogdu	677
Određivanje ogrjevne vrijednosti briketa od unutarnje i vanjske ljuske pistacija <i>Determination of calorific value of briquettes obtained using inner and outer shells of pistachio nuts</i>	
M. A. Nicolescu	685
Strateški pristup održivom korištenju obnovljivih izvora energije u rumunjskim ruralnim područjima <i>Strategic approaches for sustainable utilisation of renewable energies in Romanian rural areas</i>	
D. Tucu	695
Odnos nagiba noža i sile rezanja stabljika <i>Salix viminalis</i> var. <i>energo</i> <i>Relationship between cutter inclination and cutting force for the stalks of Salix viminalis var. ergo</i>	
S. Castellano, I. L. Tsirogiannis	703
Analiza dnevnog osvjetljenja u stakleniku s fotonaponskim ćelijama <i>Daylight analysis inside photovoltaic greenhouses</i>	
I. Blanco, E. Schettini, G. Scarascia Mugnozza, G. Puglisi, C. A. Campiotti, G. Giagnacovo, G. Vox	713
Sunčevi kolektori u sustavu hlađenja staklenika <i>Thermal solar collectors and absorption system applied to greenhouse cooling</i>	
G. Vox, I. Blanco, C. A. Campiotti, G. Giagnacovo, E. Schettini	723
Okomiti zeleni sustavi u kontroli klime zgrada <i>Vertical green systems for buildings climate control</i>	
A. Barbaresi, D. Torreggiani, S. Benni, P. Tassinari	733
Analiza toplinskog režima podruma energetskom simulacijom <i>Analysis of an underground cellar thermal behaviour based on energy simulations</i>	
C. Sica, R. V. Loisi, I. Blanco, E. Schettini, G. Scarascia Mugnozza, G. Vox	745
SWOT analiza upravljanja plastičnim otpadom iz poljoprivrede <i>Swot analysis and land management of plastic wastes in agriculture</i>	

E. M. Nagy, M. Todica, C. Cota, V. C. Pop, N. Cioica, O. Cozar	755
Degradacije škrobnih plastičnih materijala djelovanjem vode <i>Water degradation effect on some starch-based plastics</i>	
C. Alexe, M. Vintila, Gh. Lamureanu	763
Biomedicinska kvaliteta rajčica zavisno tehnologiji proizvodnje <i>Biomedical quality of tomatoes depending on culture technology</i>	
M. Vintila, Gh. Lamureanu, C. Alexe	775
Kvaliteta proizvoda dobivenih od nekih varijeteta višanja <i>Quality of processed products of some cherry varieties</i>	
J. Čepl, P. Kasal, A. Svobodova	787
Tehnologija kontrole korova u krumpiru u sustavima niskih ulaganja <i>Technology of potato weed management under conditions of low input systems</i>	
A. Galli, G. Corti, S. Cocco, E. Marcheggiani	797
Poveznica pučke arhitekture i okoliša: slučaj studije regije Marche (središnja Italija) <i>Linking vernacular architecture and environment: the case study of Marche region (Central Italy)</i>	
P. Picuno, T. Stanovčić, I. Moric, A. Dimitrijević, C. Sica	807
Vrednovanje pučkih gospodarskih zgrada za inovativni ruralni turizam <i>The valorisation of vernacular farm buildings for an innovative rural tourism</i>	
C. Sica, A. Lista, P. Picuno	819
Mehaničke karakteristike "adobe" opeke: drevni konstrukcijski elementi za ekološki prikladnu obnovu zgrada <i>Mechanical characterisation of adobe bricks: ancient constructive elements for an eco-friendly building renovation</i>	
Z. Godosi, C. Gadaleta-Caldarola, S. Goustos, V. Rigatou	829
Zelena ekonomija i poljoprivreda: najnovije stanje u Jadransko-Jonskom području <i>Green economy and organic agriculture: state of the art in the Adriatic-Ionian area</i>	
I. Grgić, M. Zrakić, J. Gugić	841
Značajke agroturističke potražnje stanovnika grada Đurđevca <i>Agritourism demand features from the Djurdjevac residents point of view</i>	
I. Grgić, M. Zrakić, J. Gugić	849
Agroturizam na području Đurđevca: ograničenja i mogućnosti razvitka <i>Agritourism in Đurđevac city area: development constraints and opportunities</i>	
S. Sito, B. Šket, M. Grubor, A. Devrnja, M. Koren, I. Maletić, H. Hrvojčec, A. Kraljević	859
Proizvodnja i potrošnja bućinog ulja u Hrvatskoj i Sloveniji <i>Consumption of pumpkin oil in Croatia and Slovenia: Consumers attitude</i>	

V. Jejčič, F. Al Mansour, T. Poje	869
Ogljični odtis vinogradniške pridelave	
<i>Carbon footprint of vineyard production</i>	
D. Mnerie, L. Gaceu, O. Gubeina, M. Shantsyan, A. Birca	879
Analiza odraza etiketa prehrambenih artikala sukladno izvoru kvalitativnih svojstava	
<i>Critical analysis of the reflection by the resources quality agro-livestock in the labeling of generated foodstuff</i>	



A HISTORY OF AGRICULTURAL LAND DRAINAGE

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ABSTRACT

Lands with excess natural moisture content that not suitable for agricultural production are widespread in humid parts of the world, including wet subtropical and tropical areas, where atmospheric precipitation exceeds evapotranspiration. In order to bring low-productive areas (marshes, the sea bottom, inundated and waterlogged territories etc.) into agricultural use and to raise the efficiency of farming, land drainage works were needed.

Drainage of agricultural land is one of the most critical water management tools for the sustainability of productive cropping systems, as frequently this sustainability is extremely dependent on the control of waterlogging and soil salinization in the rootzone of most crops.

The drainage technology had improved considerably, in parallel with the general scientific and technical progress of our civilization.

The paper present the history of surface drainage and drainage works world wide and, as a study case, the history of land drainage on Romania territory presenting evolution stages of these until 2012. Conclusions will post some recommendations for lands drainage future considering actual trends in agriculture as well as the impact of climatic changes on this field.

Key words: agriculture, land drainage, water, technology

INTRODUCTION

Agricultural land drainage history started before the ninth millennium BC, when subsurface drainage was most likely implemented by gravel and stones, or permeable, voluminous substances like bundles of small trees and shrubs tied together in the bottom of a trench. Land drainage for agricultural purposes has a long history knowing a balance between improving drainage of land presently in agricultural production and converting additional wetlands. Today, around 150 million ha need a land drainage system. Modern

land drainage is currently a key element for agriculture development and in sustainable management of environment.

METHODS

The paper is based on an extensive literature review, the analysis of historical documents respectively on interviews with people involved in agricultural drainage technique. The studies were carried out for 10 years, between 2004 and 2014.

DISCUSSIONS

Development of drainage systems began in Mesopotamia around 7000 BC year. Surface drainage was practiced because drainage tubes were nonexistent in that period. Historical data relating to the ancient Indus civilization around 2500 mentions the fact that within BC Indus Valley agriculture was practiced. A necessary surplus of water was based solely on rainfall and flooding, although in an uncontrolled manner. Irrigation and drainages, as entirely natural phenomena, were in equilibrium: when the Indus water presented high levels, a portion of the major bed was flooded while during drier periods with low river levels, these areas were naturally drained. The oldest drainage tubes were 4000 years old and were found on the lower Indus valley. The lack of drainage tubes was somehow refilled using local materials such as stone and wood. [Ami, 1987]

The first documented drainage works were carried out in the time of Amenemhat III (XIX century BC) and consisted in the reclamation of Fajun oasis (partially), probably irrigated since it was located on the lower Nile river. During Pharaoh Ramses III (VIII century BC) surface drainage is performed in the eastern part of the Nile delta. The surface drainage works practiced before the year 0 were facilitated with the use of Archimedes screw, a primitive but simply pumping station with some working principles still valid.

The existences of these impressive works have not escaped the attention of the Etruscans and later the Romans. Etruscans were owed derivative works and drying up of lakes or drainage of wetlands (eg. Chiana Valley). In his study on the ancient civilization from Middle Italy, Adameşteanu D. (1983) mentions about major works of surface drainage and drainage dating from the fifth century BC, placed under protection of Achelaos demigod, which had the gift of land purifying and improving. [Adameşteanu, 1983]

After the conquest of Etruria and the defeat of Carthage, The Roman Empire assimilated the culture of Greek colonies from southern Italy and the Greek Aegean culture, manifested in hydrotechnics by channeling through reclamation, drainage etc. Are very characteristic for today northern Africa, Algeria and Tunisia especially those underground galleries for draining aquifers, water capture and their management at great distances to avoid evaporation due to the arid climate. Major water supply pipelines, derivations and connections from Egypt and Mesopotamia, with their drainage-irrigation main function, were the source of inspiration for the Romans, who in turn have built great canals linking rivers crossing from a hydrographic basin [Botzan, 1994].

The problem of land drainage was closely analyzed and studied by M. Terentius Varo (116-28 BC), M. Vitruvius Polio (I cent. BC - 26 AD) Collumela (I cent. AD), C. Publius

Plinius Secundus (7-79 AD), Sextus Iulius Frontinus (97-103 AD) Palladius (Sec. II AD). [Botzan, 1994; Dobre, 1984]

In the 2nd century BC, Cato made some references to the need of removing water excess from agricultural fields. Thus it shows that Roman civilization knew underground drainage. Lucius Junius Moderatus Collumela, who lived in Rome in the first century AD, wrote an important study headed "De Re Rustica" in which describes how to maintain and prepare the land to be able to practice agriculture.

In Europe, the Roman Empire had executed numerous works to eliminate the excess water mentioning here the draining of Pompei marshes, drying the Rhone ponds near Arles, France. In England, the Romans installed drainage networks at the mid of the second century AD. Residents of the Netherlands have used the current drainage network on the Atlantic shore, behind the dams, to gain ground at the expense of the ocean. [Nicolau, 1970; Vaughan, 2005]

Land drainage measures were applied on actual Romania's territory from the ancient times, at the beginning in a primitive form in comparison with the actual techniques, with significant periods of time characterized by „black holes” regarding this type of works and their evolution. The first records related to the existence of some surface drainage ditches are from Neolithic period. A group of houses, situated near a watercourse, were forming a hamlet which was surrounded by a ditch with double function: fence and collector of inside waters from precipitations. These ditches, which are the ancestors of the future drainage canals, are known under the name of *fossatum* being characteristic for the Dacia's villages and future Daco-Roman settlements. [Cazacu, 1985]



Fig. 1 Surface drainage canal realized by geto-dacians [Glodariu, 1996]

Archeological researches attested that geto-dacic villages were surrounded with ditches for the inside waters collection and evacuation. The soils which resulted after the canal was created, it was used in the construction of an exterior embankment. This word, embankment ("dig" in Romanian) is of geto-dacian origin ("dhejgh"). The inhabitants from Criș and Beretău valleys (western and north-western Romania), a swampy area, couldn't be

conquered by Romans due to their skills in realizing embankments against floods, also used against enemies. [Cazacu, 1985]

The geto-dacian people had knowledge on underground drainage, this technique being used in the case of citadels from the Black Sea shores but also by citadels from Retezat-Godeanu Mountains. These citadels used the sub-surface drainage for draining the fountains waters (necessary for the water supply) and for terraces drainage. There isn't any certitude regarding the use of drainage in agricultural purposes. [Sabau, 1987]

For heavy soils, less permeable and with a small slope, without a natural adequate runoff, the problem of water excess preventing and removal – temporary and seasonal – was resolved by land improvement techniques (of Roman origin – probably that the Romans obtained this technique from Etruscans) being realized a soil surface shaping. [Botzan, 1994]

In the first half of the 1st century, L. Junius Moderatus Columella brought numerous appreciations regarding hays irrigation and humidity excess elimination from agricultural fields. In order to prevent water excess in autumn sowing he proposes the early opening of ditches for water evacuation, ditches directed to the collector channels.

On the fields without permanent humidity excess, drainage was made similarly with Cato proposal, thru deep channels filled up with rocks or wood in different quantities and percentages. These solutions kept their viability in time, ditches from autumn period, for sow works, being represented in Transylvanian agriculture. [Botzan, 1994]

If in Europe, the first subsurface drainage systems were installed at the beginning of the Christian era, there is a period of several hundred years during which this technique is forgotten.

In March 1098, a group of reformists from a monastery located near Molesme, led by Abbot Robert (1028-1111), occupied some wetlands that have been near a forest at Cîteaux (Latin Cistercium) in Burgundy, where they built a monastery loyal to Benedictine ideals and established the Cistercian Order.

With innovative ideas in the field of engineering (especially related to water power), and having a work force under direct control to implement these innovations, Cistercians soon dominated Europe in the development of techniques for obtaining new farmland and agricultural drainage. For example, the original drainage of marshes full of malaria in Lombardy and Emilia-Romagna was along a row of houses of Clairvaux Cistercian daughters. It appears that they knew the drainage technique including underground drainage with drainage tubes. [www.paradoxplace.com]

In Russian Novgorod region, researchers have identified traces of the existence of dams and drainage systems from the eleventh century. In the same period, in Bohemia, draining marshes was practiced. In the thirteenth century, the Dutch have built networks of channels to collect excess rainfall. Measures to combat floods across today Czech Republic and Slovakia are dating from the XV – XVI centuries, several surface drainage channels being realized: channel Bela (1440), Lansky channel (1450), Golden Channel (1506-1520), Opatovicky channel (1554) and Nova Reka channel (1585-1590). [Cseko, 2004; Nicolau, 1970; Vaughan, 2005]

The earliest known example of tube drainage dates from the first half of the seventeenth century (1620) and was located in the garden of a convent in France (Figure 1). Since that place had a very fertile soil even during droughts and fruit quality was outstanding, excavations were carried out which showed tubes of 10 inches long and 4 inches in diameter which were buried at 4 feet deep (approx. 1.2 m) so as to form a drainage system. Each tube had a funnel shape and was carried out in such a way that they can be joined. It seems that they were used also for subirrigation, very effective in dry periods. [Klippart, 1867]



Fig. 2 Drainage tube discovered in Mabeuge, France in 1620 [Klippart, 1867]

Middle Age distinguishes by land drainage works especially in countries from the North Sea area. People in those areas have begun to gain arable land at the expense of swamps and lakes by draining water with canals, ditches and culverts

The invasion of migratory peoples determined the native population from actual Romanian territory to retreat in safer places, finding a shelter in mountain areas, forests, swampy and mud areas where they continue to practice agriculture. Even though we don't have archaeological evidences, we can suppose that the people who were retreating in swampy areas (which were hardly accessible) used the defense technique against flooding and surface drainage in order to realize access roads and for obtaining lands for agriculture. [Botzan, 1994; Sabau, 1997]

However, in the XIII century were realized surface drainage arrangements for swamp hydroamelioration in the Bârsa Depression by Teutonic knights and German colonists. In the Dr. Florin Salvan's paper we can find the following paragraph: "The Teutonic knights and German colonists settled in a wild and inhabit region. [...] They cut forest, drained swamps, introduced agriculture, spread the crafts and commerce. Bârsa region turns from a wilderness into a beautiful garden". These Teutonic knights were preoccupied by the following types of works: they had divagated watercourses with the strategic purpose to create guarding water rings around citadels or for swamping strategic areas adjacent to German colonists villages, they had drained lands in order to obtain proper surfaces for agriculture, they consolidate riverbanks and versants, created water reserves on the watercourses for strategic controlled discharges, they had divagated watercourses for water mills etc. The hydro-defense technique was subsequently used by Hungarian mercenaries who were dislocated in adjacent counties. The Teutonic knight's labor force was formed by stonemasons from Middle Orient specializes in military and Hydrotechnical constructions (watercourses protection), carpenters from Libyan and Anatolia and unqualified native workers. [Baltescu, 1972; Salvan, 1996]

The XVth and XVIIth brought a new attitude regarding the hydroameliorative measures on actual Romanian territory. The swampy areas, the zones with a permanent waterlogging, represented efficient obstacles against enemies. These areas were part of defensive strategies and they didn't present any interest from hydroameliorative point of view.

The researcher P. Panait mention the rise of Dâmbovița Citadel as an important component of defense system created by king Vlad Țepeș (in international literature often known as Dracula), citadel which due to its position presented numerous advantages: is was surrounded by a strong belt of villages cu high economic and human potential, it was situated near important crossroads, disposes of numerous lakes and swamps localized in neighborhood which assured a safety protection. Vlad Țepeș rise Comana Monastery with role of outpost against Turks invasions. In the second half of XVII century, Paul de Alep, visiting the monastery, makes the following remark: "it is situated on an island being surrounded by lakes, slops and unfathomable swamps. [...] They say that if the Emperor will come with war, with all his army, he will not be able to defeat them, thing that appears to be true, because the monastery has a strong position, being in the middle of the lakes which didn't freeze even in the coldest winter, their bottom being with sand and mud." [Stoian, 1989; Iorga, 1939]

The swampy lands were efficiently used and by Stephen the Great, being much known and debated the battle from High Bridge from January 1475, the Romanian victory having between the main causes and the very inspired chosen of battle ground. Other memorable historical events are the victories from Rovine (XIVth century) and Călugăreni (XVIth century), the humidity excess being in these cases favorable factor for the success of Romanian armies.

In west, Timișoara's defense was concentrated on the very humid land; a swampy area situated between Timiș and Bega (former Timișel) rivers. A Turk historian, Mustafa Gelalzade noticed about Timișoara the following: "Timișoara it was a much desired citadel and it had strong walls and tower being impossible to cross them. [...] The fortresses, churches and bell towers were defended by swampy waters". In order to conquer this fortress, part of Turkish forces, during the siege from 1552, had executed land reclamation works for being possible to raise bridges over the swamps and Bega river's channels. Filippo Pigafetta, an Italian envoy, participant la Timișoara's siege under the command of Sigismund Bathory prince (1595), describes Timișoara's fortress as it follows: „[...] Timișoara is closed by a wall from wood and soil according to this country's customs and from this part it has large swamps and slops, and ditches, and deep waters around for half a mile: it is surrounded by Timiș river (there is confusion, in reality being Bega river or the Little Timiș – Timișel – for a small period of time this being the name of the river which cross Timișoara) from which it has the name". Evlia Celebi, during his voyage from 1660 to 1664, mentioned that the fortress was situated on the Timișoara river waters, this document offering us the possibility of supposing that the name of this river is a diminutive of Timiș River. [Dudas, 2004]

The defeat or at least the mitigation of enemy's forces by keeping these mud areas has been proven to be much profitable from economical, social and political point of view. That's why the hydroameliorative measures were not applied, such works being unnecessary.

In Europe, land drainage works are increasing in the XVI, XVII and XVIII centuries when drainage technique extends to all European countries but also to Russia and United States.

After Stuyt et al (2005), drainage systems were first introduced in England by Romans but these works were "forgotten" for a long time and re-appeared around 1544, when the Dutch engineers, who enjoyed a great respect, began to export in England their skills and abilities of their engineers who enjoyed great respect. The first Dutch which took a drainage job in England was Cornelius Vanderdelf, later followed by other famous engineers as Cornelius Vermuyden and Joos Croppenburgh in the early seventeenth century. [Stuyt, 2005]

A book about drainage was published in 1650 in England by Captain Walter Bligh which claimed drainage trenches as the first form of deep drainage. Another book appeared in 1758 and was composed of four volumes. It claimed that analyzed the drainage in general claimed, but actually it was limited to marshes drainage without giving any information that even other lands would require this type measure. Regarding the method of drainage, it was suggested the solution of digging trenches followed by filling them with stone, wood waste and then finally ground. This used to create water flow conditions and avoid large openings at the ground surface as a result of excavations. [French, 1860]

At the end of the Middle Ages, the Dutch started to use wind power for draining land. Windmills pump water using water wheels (since 1634) or Archimedes screw. Land under the water level was so drained. The height at which one windmill can pump water was limited.

The solution was to combine several mills, each pumping water into a reservoir located at a higher level, the last one pumping the water into a river or lake. In the eighteenth century, some "molendriegangen" (series of 3 mills) (Figure 3), and "molenviergangen" (series of 4 mills) were built. Windmills were crucial and essential for land reclamation and conservation until the advent of the steam engine driven pumps and diesel later. [van Joolen, 2003]

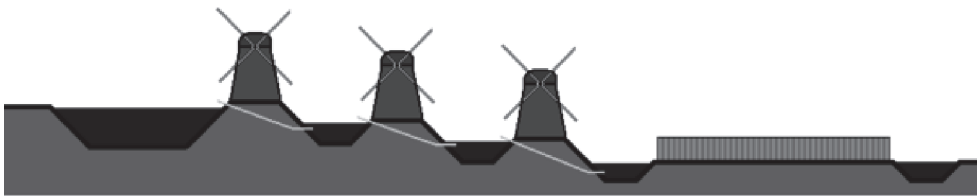


Fig. 3 "Molendriegangen" used in land drainage [van Joolen, 2003]

Great hydrotechnical works began in the XVIII century in actual Banat region (west part of Romania), the promoters being the Austrians.

The historian Francesco Grisellini indicate in the XVIII century that the western part of Romania, between rivers Aranca, Bega, Timiș and Bârzava was an area with swamps with

create unwholesome conditions of populating the region, stopping the social and economical development. All these conditions imposed measures and water regularization works and surface drainage arrangements. In 1728, under the supervising of Florimund de Mercy, military governor of Banat area, began regularization works of River Bega and surface drainages of swamps around Timișoara. Between 1728 and 1756 is regularized river Bega. [Dudas, 2004]

Maximilian Fremaunt, a Dutch engineer, had realized the project of a double connection (between Timiș and Bega Rivers) which had the purpose to assure a constant flow on Bega River in order to resolve the problem of navigability. It seems that the name of “Bega” has Dutch origins being a transformed form of Dutch word “böge” (a river section between 2 weirs). [Dudas, 2004]

It seems that in Romania (Transylvania province) the underground drainage was used since from Maria Theresa period (1740 – 1780), being utilized fire resistant bricks, the drain section being formed from a brick on the trench bottom, two bricks disposed on extremities and on more as a roof. [Cazacu, 1985]

The invention of the steam engine in the early 19th century brought a significant increase for the capacity of pumping, allowing larger areas of land to be drained or gaining new polders, for example the 15,000 ha of Haarlemmermeer, the South west of Amsterdam, in 1852. The project lasted 12 years (1840-1853), drainage being performed using a large system of canals and drainage pumps. Entire operation costs have exceeded \$ 5 million [Ritzema, 1994].

At first drain tubes were made by hand. Technological development allowed since 1834 the construction of the first machines to carry out drainage tubes. It was invented and built in England and developed rapidly in the coming years. In 1848 a machine like that was exported to USA [Ritzema, 1994].

Machines which were driven by steam engines for excavation and making trenches have begun to be used from 1890, followed by the appearance of dragline in 1906 in the United States.

In Transylvania in the late 1800s, the agricultural system allowed sealing and leveling marshes (drainage), conditions for agricultural amelioration etc. Estates splitting had to consider the possible execution of paths and drainage networks, thus appearing the first correlation between land management and hydrological works.

Until 1917, in the former Tsarist Empire, 1.8 million acres were drained, 50 years later, reaching 10.5 million. [Nicolau, 1970]

In Hungary, drainage projects at large scale started in 1880 – 1890. At the end of the 19th century were already about 2300 km of drainage channels on Danube Valley and other 3800 km on the river Tisza evacuating excess water. The length of the drainage channels will double in the following decade, 103 pumping stations being involved in drainage activities. By 1970, more than 4.5 million hectares have been drained, representing over 50% of the agricultural country surface. [Cseko, 2004; Nicolau, 1970]

In Poland, the areas with excess moisture requiring drainage works, summed 10.9 million hectares (35% of the agricultural and forestry surface of the country) in 1970. Drainage works performed included: over 1.5 million hectares pastures and meadows

respectively 3.6 million hectares of arable land. On pastures and meadows drainage was performed by open channel network while on arable lands, closed drainage occupied more than 70% of the drained surface. [Nicolau, 1970; Cseko, 2004]

The catastrophic floods from 1910 - 1912 from Romania highlighted the need for execution of larger-scale hydroameliorative works. By 1944 the hydrological situation has not improved only partly due to local arrangements. However, the dam works included an area of about 622000 ha, being correlated with defense against flooding for populated areas. Part of this area has been landscaped and with surface drainage and underground drainage works (about 360000 ha).

In 1944 the dam and drainage works in Romania covered an area of about 700000 ha (Western Lowland, Danube meadow). Most drainage works executed by 1944, drainage channels being clogged and pumping stations totally insufficient. Since 1949 were established and documented extensive studies that led to the need for reshaping and resizing dams, drainage networks and pumping stations. [Haret, 1978]

Since 1970 it was adopted a comprehensive development program for the western part of Romania being realized the most important drainage systems from this area. Following the floods from 1970, floods with great destructive effect, it was set up a national committee which drafted the National Programme on the Elimination of excess water from agricultural lands and flood control [A.S.A.S, 1973].

According with ASAS researches, in 2007 Romania had 8.62 million hectares agricultural fields affected by humidity excess from which 4.2 million hectares are affected by temporary humidity excess from precipitations, 1.97 million hectares with permanent humidity excess caused by water table and 2.45 million hectares with humidity excess caused by inundations or infiltrations from water courses. From these 8.62 million hectares, 52.55% requests direct measures of drainage.

Last dates (at level of 2004) indicate that are 8.8 million hectares which necessities ameliorative works for hydric regime correction. The surface drainage and sub-surface drainage which are in the patrimony of National Administration of Land Reclamation and Improvement cover a surface of over 3 million hectares. The excess water is evacuated by pumping stations (735 of pumping stations) from 1.463.927 ha and gravitationally from a surface of 1.621.318 ha. [www.anif.ro]

CONCLUSIONS

The floods from 2005 and after emphasize the necessity of review the problems existing in surface drainage and drainage systems in Romania.

Being design according to a specific surface drainage flow computed in 1960 – 1970, and as a result of global changes from climatic point of view which bring large quantities of precipitations, these systems are no more able to evacuate the excess of water. The afferent pumping stations of these systems must be adapted to these new conditions in order to permit the evacuation of water for precipitations and flooding.

Are imposed new measures of rehabilitation and modernization for these pumping stations, to increase the installed flow by adapting the existing pumps. Another solution,

already applied, is to install new submersible pumps which will function in parallel with the existing ones. The solution is very expensive and not all the time has the necessary efficiency. An ingenious solution preview constructive changes at engines and pumps thru their capsulation in order to be able to function in flooded conditions.

Given being the important percent of humidity excess fields in agricultural frame and because of the large number of social and economical objectives find it out in these areas, the problem of surface drainage and drainage works in a very important one.

The strategy in surface drainage and drainage domain will have to take in consideration the following aspects:

- Ecological aspect for new arrangements but also for the existing ones taking the necessary measures to ecologies them;
- New evaluation of existing arrangements in order to establish opportunities for bringing new technologies but also considering the connection drainage – irrigation in condition of rising irrigation efficiency;
- Analyses from economical point of view of salty areas, with land slides respectively sandy for establishing the opportunity of applying land reclamation and improvement works;
- Establishing the opportunity of previewing, financing and implementing monitoring works for land reclamation and improvement systems;
- Will be granted a special attention to the existing arrangements for their exploitation through regulations periodically adapted to requests, realizing reparations and maintenance works according to actual standards and also organizing an efficient supervising and protection system for existing works.

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AGRICULTURAL SOIL COMPACTION UNDER THE ACTION OF AGRICULTURAL MACHINERY

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SUMMARY

Artificial compaction of agricultural soil consists in the increase of soil bulk density, respectively in the decrease of soil porosity, especially due to the contact with the tires or tracks of tractors and agricultural machinery. This paper aims to determine the pressure on the soil, by simulating real field conditions in the laboratory. Experiments were conducted using a complex testing system in accelerated regime, which can simulate the static pressure at compression of the tires on the soil (stationary machinery). For each experiment were taken into account: the dimensional characteristics of the tires, testing conditions in operation and also the dynamic characteristics of the tires (when tested in real conditions).

Key words: artificial compaction, soil, tire, agricultural machinery, static pressure

INTRODUCTION

Soil is subjected to continuous degradation due to climate change, floods, acid rain, intensive and inappropriate works, for which almost all governments of the world are trying to take measures in order to protect soil by appropriate conservative measures. One of the main factors leading to soil degradation is compaction [1, 2, 3, 4, 7, 13, 15, 19]. The reason for increase of soil degradation by compaction is largely due to the increased mass of agricultural machinery and tractors (due to the desire to increase the working capacity), the intensive use of agricultural machinery even in unfavorable soil conditions, the desire for higher yields (when are performed more operations of hoeing, herbicide, irrigation, etc.)

and due to improper crop rotation [23]. They are directly influenced by growth of population, economic pressure and structural changes in modern agriculture. Soil compaction is also an environmental problem [19], being one of the causes of erosion and soil flooding [17].

The consequence of soil compaction is the limiting of root growth and inhibition of plant development and thus the reduction of agricultural production [29]. Deep compaction can persist for a long period of time and, therefore, it can threaten soil productivity for a long time [22, 24, 29]. Efforts to improve deep compaction by deep loosening of soil are often expensive and inefficient, which is why it is best to prevent soil compaction by using appropriate or conservative technologies [6]. Studies conducted by many researchers have highlighted that the risk of undesirable changes in soil structure can be reduced by limiting the mechanical stress applied on soil [8, 9, 11], and by limiting the precompression stress [26]. Nowadays, the impact of agricultural machinery on soil properties can be simulated [28] by means of compaction models [5, 10, 12, 14, 19, 20, 25], which are an important tool for the developing strategy in order to prevent soil compaction [16, 18, 21, 27].

Due to compaction, soil not only that becomes denser but also more rigid and therefore soil will be processed with greater difficulty, increased energy consumption, while its friability decreases (the shredding capacity). As a result of increasing soil stiffness, the necessary traction forces and fuel consumption for soil processing will increase, and these increases lead to increased emissions and engines combustion gas, which ultimately contribute to global warming of the atmosphere. Increasing of necessary energy has negative influences on the farmer's budget, so it is important to limit the costs for soil tillage in order to optimize profits.

Thus is required the decrease of number of tillage operations and thereby of energy consumed by the machinery, while tillage works must be more efficient and executed in proper conditions. Soil structure obtained by processing is strongly affected by soil moisture, and there is certain moisture for optimal soil processing, called *optimal moisture*. In [15] Dexter showed that the proportion of lumps produced by soil processing at optimum moisture is higher for degraded soils.

Prevention of soil compaction is a significant measure in order to maintain or improve soil quality. Soils with good physical properties, qualitative, are easy to process, which is a prerequisite condition for reducing the energy required for their processing.

Soil compaction consists in the increase of bulk density respectively the decreasing of porosity due to natural causes such as: the impact of raindrops, soil wetting, internal soil water tensions. An important role has artificial compaction due to the contact with tires or tracks of tractors and agricultural machinery. Knowing the behavior of the soil under the action of these running bodies is particularly important because, optimization of the ground pressure allows the reducing of the negative effects of surface compaction and also of depth compaction.

As Gill and Vandenberg show [17], since 1968, in agriculture, soil compaction actually affect the development environment of crop. Compaction reduces soil permeability to water, so that the water flow is facilitated in soil surface, which implies the occurrence of erosion and prevents proper recovery of soil moisture content. Compaction also reduces soil aeration, with direct negative consequences on the metabolic processes occurring in plant

roots. Another negative effect of soil compaction for agriculture is the increase of mechanical strength, thus being delayed the development of roots. Together, all the effects mentioned can reduce the quantity and quality of agricultural products.

Between the use of machinery and soil compaction, between this and the environmental parameters of plant development, and also between the environment of development and the level of agricultural production, there are direct qualitative relationships of type cause-effect. This raises the following two issues: soil may be too compact to be effectively used in agricultural production, imposing the prevention and reduction of this phenomenon; on the other hand, the soil can be insufficiently compact to be used for the construction of roads, dams, or building foundations. In the latter case the problem arises for obtaining the maximum degree of compaction with minimal effort.

The degree of compaction is a static property (characteristic) of soil [17]. The properties of a particular soil type (as material) generally do not change when its state of compaction undergoes changes. *Compaction* is defined as the dynamic behavior of the soil by which its degree of compaction increases [17]. The action of compacting must be described mathematically, by equations that take into account the forces that cause it. From this point of view, there are two main types of forces: first, there are mechanical forces generated by machinery and animals. These forces are applied for short periods of time and can be measured relatively easily. The second category of forces includes natural phenomena. For example, drying has as effect soil compaction. Forces in the latter category act for long periods of time, are difficult to define and hard to measure. Estimating the degree of compaction can be made only by means of precise equations that describe the behavior of soil compaction. In an attempt to develop these equations, outstanding scientific efforts were made. Agricultural soil is a heterogeneous material, multiphase, dispersed, structured and porous, whose nonlinear behavior in interaction with various working or running bodies is difficult to model mathematically, in this purpose being used some simplifications and idealizations.

MATERIALS AND METHOD

Experimental research to determine the pressure on the soil, at different working depths, were made under simulated regime on a stand where, with the aid of a hydraulic cylinder, were simulated the static compression pressures on the ground for the tires of some agricultural machinery.

The stand used for these experiments where was simulated the static compression test is part of a testing equipment under simulated and accelerated regime, Hidropuls type (fig. 1) and is composed of: a box with a volume of 1 m³ made of reinforced sheet with thickness of 3 mm, with dimensions: 1 x 1 x 1 [m], which was filled with soil in which were placed 8 sensors (FlexiForce), on depth, from 10 to 10 cm, starting from 5 cm to 75 cm (fig. 2).

The connection between the laptop and force measurement system (Flexi Force Tekscan sensors, type W-B201-L, with maximum domain used for this test 10 N / 50.24 mm²) was achieved through an adaptation module (formed by amplifiers and analog-to-digital converter), coupled to a serial interface 4RS232 to coupling view (USB), an adaptation module (acquisition system) and laptop (fig. 3).



Fig. 1 Equipment for testing under simulated and accelerated regime, Hidropuls type



Fig. 2 Flexi Force sensor placed in the soil at various depths (5-75 cm)



Fig. 3 Connection of Flexi Force sensors placed in the soil to the acquisition system and laptop

Before starting the experiments, soil moisture was measured for each test performed. This was done using a soil moisture meter, type HH2 (fig. 4).

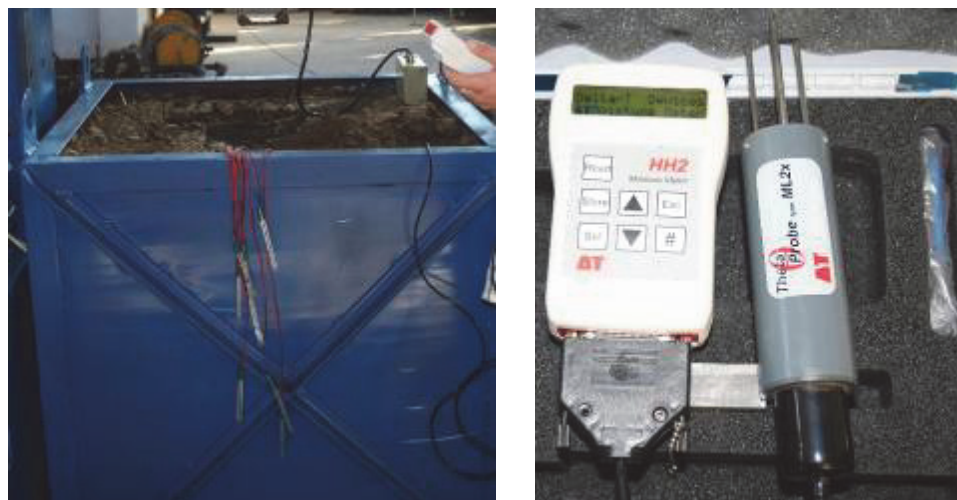


Fig. 4 Measuring of soil moisture

Simulation of static pressure exerted by the tire on the soil was done using 2 steel plates, with thickness of 15 mm and dimensions (L x W) similar to the footprint (contact area) of a wheel of tractor / combine / agricultural machinery whose touch was intended to simulate.

Pressing on the plates (which simulated the footprints) was carried out by means of a 10 kN cylinder and some intermediate devices (fig. 5).



Fig. 5 Simulation of tire pressure by pressing on the plates with a hydraulic cylinder

RESULTS AND DISCUSSION

The research for the determination of the static pressure on the soil, to depths varying between 0÷75 cm were carried out for 3 types of tires:

- Front tire (drive wheel) of a 65 HP tractor U650 (7.5-20, 8PR D-191);
- Rear wheel of a 45 HP tractor U445 (11.2 R 28, V-97);
- Front tire (drive wheel) of a C 110H grain harvester (18,4-26, 8PR D-165R3).

Dynamic running parameters of the tires (table 1) were determined in real operating conditions, taking into account the masses of the three vehicles being tested (on which base was established the mass distribution on each axle) and normal working pressures.

Table 1 Effective dynamic running parameters of the tires

	Vehicle on which were tested	Load /pressure on/in tire		Contact area on soil	Ground pressure	Rolling circumference	Deformation under load	
		[kg]	[bar]				Lateral	Radial
				[cm ²]	[daN/cm ²]	[cm]	[%]	[%]
F/D	Tractor U650 (7.5-20, 8PR D-191)	585	2.0	648	1.58	275.2	6.8	6.5
S/M	Tractor U 445 (11.2 R 28, V – 97)	550	1.2	874	1.17	371.4	3.3	5.4
F/M	Harvester C110H (18.4-26, 8PR D-165R3)	3120	1.6	2667.5	1.7	408.3	10.8	10.4

where: F – front; S – Rear; M – drive; D – direction.

To simulate the static compression test of the 3 type of tires:

A. Front wheel, tractor U 650; B. Rear wheel, tractor U 445; C. Front wheel, harvester C110H

Two plates were used with thickness of 15 mm and dimensions [L x W] similar to tire footprints, varying the displacement of piston stroke and the duration of load (table 2), and soil moisture in the area where experiments were conducted was 26.9 %.

Table 2 Testing characteristics of the three tires

No.	Plate dimension (contact area)	Size of contact area	Piston stroke displacement	Duration of load	Maximum applied force
	[cm x cm]	[cm ²]	[cm]	[s]	[N]
Soil moisture = 26.9 [%]					
A.	18 x 36	648	1.8	55.05	7380
B	38 x 23	874	2	130.6	4820
C	52.5 x 51	2667.5	1.17	20.75	10000

For the static compression test it was determined pressure in the soil, measured by the 8 sensors, starting from the depth of 5 cm to 75 cm (see table 3 and fig. 6, 7, 8 and 9).

Table 3 Static compression test

Sensor No.	Depth at which the sensor is mounted	Compressing force	Size of contact area	Presssure in the sol
	[cm]	[N]	[cm ²]	[N/cm ²]
A. DRIVE WHEEL (FRONT) TRACTOR U 650M				
-	0,1	7380	648	11,38888889
1	5	3.578	0.5024	7.121815287
2	15	3.489	0.5024	6.944665605
3	25	1.349	0.5024	2.685111465
4	35	2.043	0.5024	4.066480892
5	45	1.279	0.5024	2.545780255
6	25	0.7701	0.5024	1.532842357
7	65	0.6873	0.5024	1.368033439
8	75	0.3296	0.5024	0.656050955
B. DRIVE WHEEL (REAR) TRACTOR U 445				
-	0.1	4.820	874	5.51487414
1	5	0.588	0.5024	1.170382166
2	15	0.8286	0.5024	1.649283439
3	25	0.5699	0.5024	1.134355096
4	35	0.8396	0.5024	1.671178344
5	45	0.3519	0.5024	0.700437898
6	25	0.499	0.5024	0.993232484
7	65	0.4959	0.5024	0.987062102
8	75	0.3921	0.5024	0.780453822
C. DRIVE WHEEL (FRONT) HARVESTER C 110H				
-	0.1	10.000	2.667.5	3.748828491
1	5	1.478	0.5024	2.941878981
2	15	1.914	0.5024	3.809713376
3	25	1.179	0.5024	2.346735669
4	35	1.474	0.5024	2.933917197
5	45	1.187	0.5024	2.362659236
6	25	0.8071	0.5024	1.606488854
7	65	0.5856	0.5024	1.165605096
8	75	0.03472	0.5024	0.06910828

$$S = \pi \cdot R^2 = 3.14 \times 16 = 50.24 \text{ mm}^2 = 0.5024 \text{ cm}^2 \text{ (sensor surface);}$$

where: R = 4 m (diameter of contact button: $\phi = 8 \text{ mm}$).

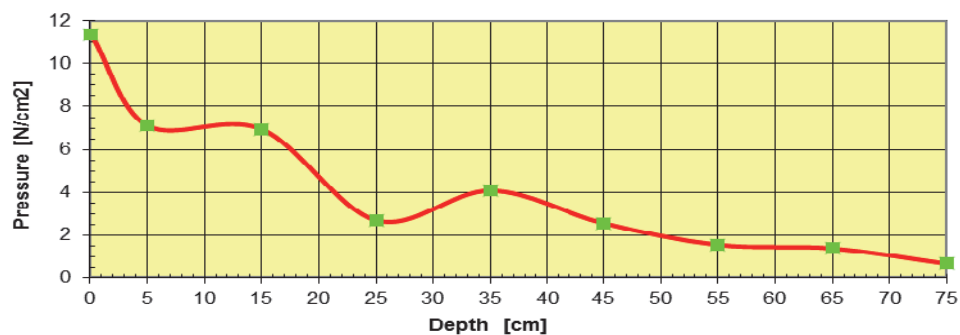


Fig. 6 Variation of pressure exerted on soil with depth, by the drive wheel (front) of tractor U 650M

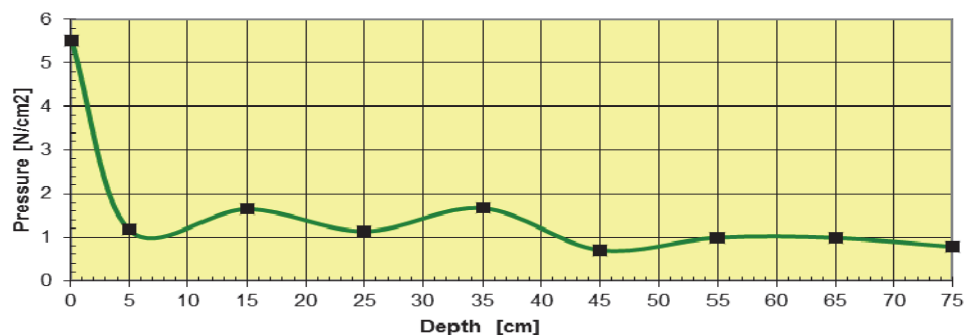


Fig. 7 Variation of pressure exerted on soil with depth, by the drive wheel (rear) of tractor U 445

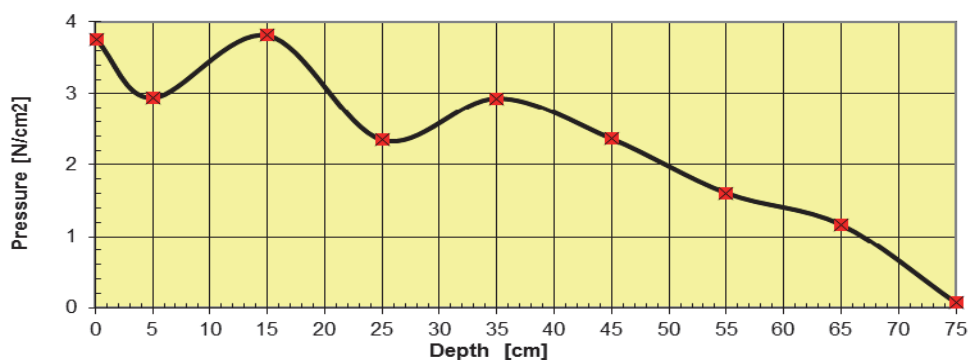


Fig. 8 Variation of pressure exerted on soil with depth, by the drive wheel (front) of harvester C 110H



Fig. 9 Aspects from the measurements and data acquisition

CONCLUSIONS

The pressure exerted on the soil was determined for 8 different depths: 5; 15; 25; 35; 45; 55; 65 and 75 cm, at which were placed in the soil the 8 sensors, on the acting direction of compressive force.

- A.** To simulate the pressure exerted by the wheel (front) of tractor U 650 was applied a compressive force of 7380 N, gradually until it reached the value determined under field conditions (7380 N), when the forces were measured in each of the 8 depths using the 8 sensors. As can be seen in the diagram of figure 6, the pressure exerted on the soil has, at first, uneven distribution, a sharp decrease to values of about $7.12 \text{ [N/cm}^2\text{]}$ at 5 cm, decreases to $2.68 \text{ [N/cm}^2\text{]}$ at 25 cm, then increases to $4 \text{ [N/cm}^2\text{]}$ and then finally follows a downward curve, with the increase of depth at which the values were measured (from 35 cm to 75 cm depth).
- B.** To simulate the pressure exerted by the wheel (rear) of tractor U 445, was applied a compressive force of 4820 N, in the same way as the previous test, until it reached the value determined under field conditions (4820 N), by measuring the forces corresponding to the 8 depths specified above. From the diagram of figure 7 it can be observed the same shape as for the other tire, the pressure exerted on the soil having at first uneven distribution, with a decrease to values of about $1.15 \text{ [N/cm}^2\text{]}$ at 5 cm, increases slightly at 15 cm, decreases at 25 cm, and then increases to $1.67 \text{ [N/cm}^2\text{]}$ at 35 cm, and then finally follows a downward curve with the increase of depth at which the values were measured (from 55 cm to 75 cm depth).
- C.** To simulate the pressure exerted by the wheel (front) of harvester C110H was applied a compressive force of 10.000 N, in the same manner and following the same steps as in the other two tests. From the diagram in figure 8 is observed that the pressure on the soil at depths of up to 35 cm has uneven variation, and then follows a descending curve, with the increase of depth at which the values were measured.

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INFLUENCE OF AGRO-MEASURES ON SOIL PHYSICAL PARAMETERS IN ALTERNATIVE FARMING

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SUMMARY

Alternative farming systems are used to cultivate high quality food products and retain the viability and fertility of soil. The field experiments of different farming systems were conducted at Joniškėlis Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry in 2006–2013. The soil of the experimental site was Endocalcari-Endohypogleyic Cambisol (CMg-n-w-can).

In different farming systems, farmyard manure, straw and green manure catch crops used for fertilization both in the soil low in soil organic matter and in the moderate in soil organic matter. In the 0–20 cm depth layer it had a more significant effect on soil moisture than on other physical soil properties. In the agricultural systems, in which catch crops had been grown, soil physical characteristics did not differ significantly before their biomass incorporation, except for the moisture content, which was lower in rainy periods and higher in drier periods than in the soil without catch crops. Soil bulk density and porosity in the topsoil layer were more dependent on soil organic matter content than on agricultural measures used: in the moderate in soil organic matter content, compared with the low in soil organic matter, bulk density was by 1.4 % lower, and porosity by 1.8 % higher.

The research findings create a possibility to make improvements in alternative cropping systems by choosing organic fertilizers and catch crops' combinations that have sustainable effect on soil and that maintain sustainability of soil productivity parameters. Rational fertilization systems, securing stability of soil productivity parameters and crop rotation productivity will promote development of organic agriculture.

Key words: agro-measures, soil physical parameters, organic farming, sustainable farming

INTRODUCTION

Plant nutrition in all ecosystems not only depends on fertilization intensity or soil richness in organic matter but also on physical parameters – bulk density, structure, number of pores with the optimum moisture and air ratio available to plants (Loveland, Webb, 2003; Hadrian et al., 2006).

Due to cation sorption receptivity, influenced by soil organic matter content, soil bulk density is one of the main properties on which water, air and thermal regime, biological activity and plant rooting depend. As a result of natural and anthropogenic factors it is the most variable value. After having used mechanical loosening implements soil settles only within certain time and remains stable for a longer period. Such density is called equilibrium density and it can be described as a physical state of certain soil. In heavy soils the optimum interval of density variation is lower than that of light soils. Soil bulk density is influenced by a great number of factors such as moisture content during pre-sowing loosening and after it and loosening intensity, therefore, the constant patterns of density variation are difficult to establish during crop rotation. Depending on moisture content the optimum soil bulk density in the soil of heavy texture ranges between 1.20 and 1.35 and in light loam soils – between 1.3 and 1.5 Mg m⁻¹ (Velykis et al, 2003). Low soil bulk density determines an insufficient contact between soil and plant roots as too large air gaps form and capillary moisture regime favorable for plant formation is not achieved; huge bulk density influences the worsening of aeration and the increase of soil hardness, moisture regime and porosity are disturbed which change the supply of plants with nutrients, root growing and development are worsened as well as plant productivity is reduced (Cassel, 1982, Rasmussen, 1999, Lampurlanes, Cantero-Martinez, 2003).

With the increase of bulk density, which is a limiting factor for water and air permeability, the sensitivity of soil to degradation increases as well as basically it is a non-renewable resource with a high degree of degradation and a very low degree of regeneration. Due to negative anthropogenic activities soil self-regulation processes are deregulated and they reduce its ability to regain the balance required for performing the whole spectrum of the most important functions as well and as long as possible. Therefore, the optimization of soil resources in order to increase the efficiency of its use and reducing the environmental degradation processes is one of the major tasks for agricultural science (Directive of the European..., 2006).

METHODS

Research object

Organic and sustainable cropping systems on a *Cambisol* with different soil organic matter content, their effects on the sustainability of major soil parameters and crop productivity in the crop rotation – spring barley (*Hordeum vulgare* L.) + undercrop → mixture of perennial grass (red clover (*Trifolium pretense* L.) cv. 'Vyliai' and meadow fescue (*Festuca pratensis* Huds.) cv. 'Dotnuva 1') → winter wheat (*Triticum aestivum* L.) cv. 'Ada' → pea (*Pisum sativum* L.) cv. 'Pinochio'.

Experimental design: soil organic matter content – factor A: low soil organic matter, content – 1.90-2.01 %; moderate soil organic matter content – 2.10-2.40 %.

Cropping systems – factor B: organic I, organic II, sustainable I, sustainable II (Table 1).

Research was done in the crop rotation's grass-cereal sequence – perennial grass of the 1st year of use (aftermath for green manure) → winter wheat + catch crops (for green manure) → pea. Plant fertilization in different cropping systems and green-manure catch crops grown during winter wheat post-harvest period are shown in table 1.

Table 1 Cropping systems, plants of the crop rotation sequence and fertilization

Cropping system (Factor B)	Plants of the crop rotation sequence and fertilization		
	perennial grass	winter wheat	pea
Organic I	-	aftermath of perennial grass	straw + narrow-leaved lupine (<i>Lupinus angustifolius</i> L.) and oil radish (<i>Raphanus satinus</i> var. <i>Oleifera</i> L.)
Organic II	-	farmyard manure 40 Mg ha ⁻¹ + aftermath of perennial grass	straw + white mustard (<i>Sinapis alba</i> L.)
Sustainable I	-	farmyard manure 40 Mg ha ⁻¹	straw + N ₃₀ + white mustard and buckwheat (<i>Fagopyrum exculentum</i> Moench.)
Sustainable II	P ₆₀ K ₆₀	aftermath of perennial grass + N ₃₀ P ₆₀ K ₆₀	straw + N ₃₀ N ₁₀ P ₄₀ K ₆₀

Soil

The parent soil material is glacial lacustrine clay lying on morainic loam. Predominant soil type of the larger part of this region according to FAO/UNESCO (1997) is *Endocalcari-Endohypogleyic Cambisol* (CMg-n-w-can), according to texture – clay loam on silt clay with deeper lying sandy loam. At the beginning of the experiment, soil agrochemical properties at the 0-20 cm layer varied: in low soil organic matter 1.90-2.01 %, available phosphorus (P₂O₅) – 67-120 mg kg⁻¹, available potassium (K₂O) – 172-220 mg kg⁻¹; in moderate soil organic matter content– 2.10-2.40 %, available phosphorus (P₂O₅) – 115-145 mg kg⁻¹ and available potassium (K₂O) – 220-230 mg kg⁻¹. Soil bulk density in the ploughlayer was 1.42-1.48 Mg m⁻³, total porosity – 43.1-45.1 %.

Experimental parameters

The experiment was set up in a crop rotation spread over time and space. Each replication was composed of two different soil organic matter content levels (factor A), and each latter one was composed of another four different cropping systems (factor B). A randomised plot design was used with the main plot size of 21 x 5 = 105 m² and harvested plot size of 14 x 2.3 = 32.2 m².

Agrometeorology

Meteorological conditions were assessed based on the data obtained from the Joniškėlis Experimental Station's meteorological site. In the spring 2006, winter crops resumed

vegetative growth in April, which was dry, with a precipitation amount of only 62.3 % of the long-term rate (40 years period), and the air temperature close to the long-term mean (30 years period). The summer was extremely dry with the amount of rainfall: in May 71.3 %, in June 11.4 % and in July 4.12 % of the long-term mean, therefore the yield of the main crops was low. In August-October the amount of rainfall exceeded the long-term mean by 85.5 mm, the air temperature was also higher, which resulted in intensive development of catch crops. In 2007, the main crops' growing period (May-July) was conducive to their development, there was a shortage of moisture during the post-harvest period, as a result, catch crops developed slowly. In 2008, plants resumed vegetative growth in the middle of April, in May the amount of rainfall was by 32.7 mm lower than the long-term mean. In August, the amount of rainfall was by 48.6 mm higher than the long-term mean, which secured optimal growth of plants. In 2009, April and May were dry, which inhibited winter wheat tillering and spring crops' germination and establishment. However, June and July were very wet with the amount of rainfall of 80.9 and 107.6 mm, respectively, which determined good winter wheat yield, but heavy rain, which occurred in July worsened the yield quality. September was very dry with 35.4 % less rainfall, and the average daily temperature of the month 1.7 °C higher, compared with the long-term mean, which slowed catch crops' development. In 2010, April 61.2 % of the long-term precipitation rate fell and the average air temperature was close to the long-term average. In May the precipitation accounted for 34.2 % more and it was slightly warmer compared to the long-term average values. June and July were close to the long-term averages both in terms of precipitation and temperature. In 2011, April-July temperature was slightly higher than usual. In the beginning of plant vegetation the precipitation was twice as low compared with the long-term average values. June was close to the long-time average and in July the amount of precipitation was 72.4 % higher than usual. In 2012 July was slightly warmer and some more precipitation fell compared with the long-term average. It was somewhat warmer in August and October than usual; the precipitation in September was 2.6 times more abundant and in October – 26.7 % less compared with the long-term average. In 2013, April was 25.8 % colder than usual, the amount of precipitation corresponded to the long-term average rates. During the entire vegetation period the temperature in May-August was warmer than usual. However, in June-August the amount of precipitation was 23.4–42.6 % lower than usual.

Physical properties of soil

The samples of soil to identify bulk density, moisture content, total porosity, pores filled with moisture and air and the nutrients available to plants were taken from the depths of 0–10 and 10–20 cm after harvesting plants from each plot.

The soil bulk density was established by the Katchinsky method and calculated by using the following formula:

$$T = \frac{D}{K}$$

where:

T – soil bulk density Mg m^{-3} ;

D – mass of absolutely dry soil g;

K – volume of cylinder cm^3 .

Total porosity was calculated by using the following formula:

$$P = \left(1 - \frac{T}{N}\right) \cdot 100$$

where:

P – total porosity %;

T – soil bulk density Mg m^{-3} ;

N – soil particle density Mg m^{-3} .

Aeration porosity was calculated by using the following formula:

$$P_{\text{aerac.}} = P - (L \cdot T)$$

where:

$P_{\text{aerac.}}$ – aeration porosity %;

P – total porosity %;

L – soil moisture content %;

T – soil bulk density Mg m^{-3} .

Methods of statistical data evaluation

The experimental data of plant productivity and chemical composition indicators were processed by a two-factor analysis of variance and correlation-regression methods using a software package *SELEKCIJA*. The symbols * and ** denote statistically significant at 95% and 99% probability level (Tarakanovas, Raudonius, 2003).

RESULTS AND DISCUSSION

Soil bulk density and porosity

While analysing the data of the research performed it was established that on the basis of the average data of a 4-field crop rotation in the low of soil organic matter content the highest density of the entire topsoil was observed in Organic I agriculture system and it accounted for 1.48 mg m^{-1} (Table 2). The density decreased by 2.00 and 1.40 % compared with Organic II and Sustainable I agriculture systems which use manure and green manure for fertilization. Significantly lower density in soil was established in Organic II agriculture system with the application of green manure and the average use of NPK fertilizers compared with Organic I agriculture. Marginal variations in density between the agriculture systems (from 1.42 to 1.45 mg m^{-1}) were established in the average of soil organic matter content as well as a density decrease compared with that established in the soil of lower productivity. Therefore, we can propose that soil bulk density partially depends both on the

mechanical effect of agricultural machinery and the amount of organic matter; and soil organic matter content increase has positive influence on the physical properties of brown clay loams as it is maintained in the literature. It has been established that fertilization of soil with organic fertilizer has a positive effect on agro physical properties which are quite stable in clay loams (Tataw et al., 2014). The stability of soil aggregates depends on the amount of organic matter which in its turn is influenced by plant residues (Razafimbelo et al., 2008, Kriaučiūnienė et al., 2012).

Table 2 Influence of catch crops grown after winter wheat on soil bulk density

Cropping system (Factor B)	Soil bulk density		
	0–10 cm	10–20 cm	0–20 cm
Low soil organic matter			
Organic I	1.43	1.52	1.48
Organic II	1.40	1.50	1.45
Sustainable I	1.41	1.51	1.46
Sustainable II	1.37*	1.48*	1.42*
On average factor A	1.40	1.50	1.43
Moderate soil organic matter			
Organic I	1.40*	1.51	1.45*
Organic II	1.39*	1.48	1.44*
Sustainable I	1.36*	1.50	1.43*
Sustainable II	1.38*	1.45*	1.42*
On average factor A	1.38	1.49	1.43
On average factor B			
Organic I	1.41	1.51	1.46
Organic II	1.40	1.49	1.45
Sustainable I	1.38*	1.50*	1.44
Sustainable II	1.38*	1.47	1.42
LSD ₀₅ A	0.015	0.019	0.012
LSD ₀₅ B	0.022	0.027	0.017
LSD ₀₅ AB	0.031	0.039	0.025

Unfortunately, the correlation analysis performed during our research indicated that the bulk density of the soil of low productivity in the upper 0–10 cm layer had low dependence ($r=0.463$) on soil organic matter amount and in the deeper soil layer (10–20 cm) it was even lower ($r=0.224$). Having assessed the influence of the upper and lower layers on each other the dependence of average intensity was established ($r=0.546$).

The dependence of average intensity ($r=0.509$) on a soil organic matter amount was established in the upper layer of average productivity soil. Weak dependence ($r=0.227$) of density on the soil organic matter amount was established in a deeper layer of average productivity soil. Having evaluated the influence of the soil bulk density of the upper and lower layers on each other week dependence was established between them ($r=0.184$).

This fact shows that the agro measures applied in different agriculture systems both in the soils of low and average productivity did not ensure positive effect on density which exceeded the amount recommended in the literature due to the amount of large physical particles and low soil organic matter content in clay loam.

Table 3 Influence of catch crops grown after winter wheat on soil porosity

Cropping system (Factor B)	Soil porosity		
	0–10 cm.	10–20 cm.	0–20 cm.
Low soil organic matter			
Organic I	46.63	45.03	45.83
Organic II	47.68	44.19	45.93
Sustainable I	47.52	44.05	45.79
Sustainable II	48.89*	45.15	47.02*
On average factor A	47.68	44.61	46.14
Moderate soil organic matter			
Organic I	48.02*	44.13	46.07
Organic II	48.09*	45.84	46.97*
Sustainable I	49.43*	44.25	46.84*
Sustainable II	48.59*	46.05	47.32*
On average factor A	48.53	45.07	46.80
On average factor B			
Organic I	47.32	44.58	45.95
Organic II	47.88	45.02	46.45
Sustainable I	48.48*	44.15	46.31
Sustainable II	48.74*	45.60*	47.17*
LSD ₀₅ A	0.570	0.640	0.441
LSD ₀₅ B	0.806	0.905	0.624
LSD ₀₅ AB	1.140	1.280	0.883

Soil total porosity is an important property of soil on which water and air regime and plant growth conditions depend – it varies inversely with soil bulk density. The investigations show that the variations of soil bulk density and total porosity depended on the fertilization of agriculture systems (Table 3). On the basis of the average data of 2006-2009 it was established that significantly higher (4.85 %) total porosity was observed in Sustaina-

ble II agriculture system compared with Organic I. An increase in the total porosity was established in Organic II and Sustainable I agriculture systems compared with Organic I, however, these variations are insignificant. There were no significant variations established between the agriculture systems in the average of soil organic matter content. On the basis of the average data significantly higher total porosity was established in the upper soil layer of both soil organic matter backgrounds in Sustainable I and II agriculture systems – 2.45 and 3.00 % higher respectively compared with Organic I. The total porosity in the upper topsoil layer of the soils both of low and average productivity corresponded to the theoretical requirements and varied within the range of 46.63–48.89 % and 48.02–49.43 % respectively.

Having performed correlation analysis it was established that the upper layer (0-10 cm) porosity of the soil of lower productivity had weak ($r=0.47$) dependence on the soil organic matter and in the case of the average productivity soil average intensity dependence ($r=0.51$) was established.

It was established that in the lower (10–20 cm) soil layer investigated the total porosity was lower than recommended, however, there were no significant differences between the agriculture systems and the fertilization applied. As a certain density increasing tendency, though insignificant, was established in this layer the total porosity had a decreasing tendency. There was a weak correlation between porosity and organic soil matter established in the deeper layer of the soil of low and average productivity: $r=0.05$ and $r=0.22$ respectively. A weak correlation was also established between the top and deeper layers of the investigated soil, $r=0.17$ – in low soil organic matter and $r=0.10$ – in average soil organic matter.

Soil Moisture and its Resources

It is a morphological property depending on the amount of precipitation, air temperature, relief, the depth of ground water, texture, growing plants, evaporation and penetration into deeper layers. Soil moisture content affects both organic matter and its intensity of decomposition (Wolf et al., 2003). Depending on moisture conditions the decomposition of organic matter takes place under aerobic and anaerobic conditions (Tataw et al., 2014). Moisture content is also one of the factors affecting soil physical properties most. With the increase of density permeability to moisture decreases and limnoglacial loams by their nature are distinguished for low permeability to moisture due to their clay particles.

While analysing the data of the research performed it was established that the organic and mineral fertilizers or their mixtures applied in the upper layer of the soils of low productivity had no significant influence on moisture content. Having performed correlation analysis it was established that the moisture in the low of soil organic matter content had dependence of average intensity ($r=0.54$) ($P<0.05$) on the organic materials present in the soil (Table 4).

Moisture content in the soil of average soil organic matter content was higher compared with the low soil organic matter content, however, the comparison of the fertilization applied in the agriculture systems yield no significant differences and low ($r=0.10$) dependence on soil organic matter content was established.

Table 4 Influence of catch crops grown after winter wheat on soil moisture content

Cropping system (Factor B)	Soil moisture content		
	0–10 cm.	10–20 cm.	0–20 cm.
Low soil organic matter			
Organic I	19.05	18.68	18.86
Organic II	19.03	17.97*	18.50
Sustainable I	19.25	18.15	18.70
Sustainable II	19.57	18.99	19.28*
On average factor A	19.23	18.45	18.84
Moderate soil organic matter			
Organic I	20.07*	18.62	19.35*
Organic II	19.88*	18.61	19.24
Sustainable I	20.23*	18.54	19.39*
Sustainable II	19.84*	19.22	19.53*
On average factor A	20.01*	18.75*	19.38*
On average factor B			
Organic I	19.56	18.65	19.11
Organic II	19.45	18.29	18.87
Sustainable I	19.74	18.34	19.04
Sustainable II	19.70	19.11*	19.40*
LSD ₀₅ A	0.292	0.276	0.205
LSD ₀₅ B	0.413	0.390	0.290
LSD ₀₅ AB	0.584	0.551	0.409

In the deeper (10-20 cm) layer of the low soil organic matter content significantly lower – 3.8 % moisture content was established in Organic II agriculture system compared with Sustainable I. Significant variations in the low soil organic matter content of Sustainable agriculture systems were not established as in the soils of average soil organic matter content of different agriculture systems. The correlation analysis performed indicates that weak relationship with soil organic matter content was established both in the soils of low and average productivity, $r=0.04$ and $r=0.23$ respectively. It was established that the relationship between the investigated upper and lower layers of the low soil organic matter content was weak ($r=0.12$) and this relationship in the higher soil organic matter content was of average ($r=0.56$) intensity.

CONCLUSIONS

Having summarised the results of research of various alternative cropping systems, investigated over the 2006–2013 period in the crop rotation sequence – perennial grass-

winter wheat-pea in a clay loam *Endocalcari-Endohypogleyic Cambisol (CMg-n-w-can)* with a different soil organic matter status, the following conclusions were made:

In different cropping systems, farmyard manure, straw and green manure catch crops used for fertilization both in the low and moderate soil organic matter, in the 0–20 cm depth layer had a more significant effect on soil moisture, than on other physical soil properties. In the cropping systems with catch crops, soil physical characteristics did not differ significantly before their biomass incorporation, except for the soil moisture content, which was lower in rainy periods and higher in drier periods, than in the cropping systems without catch crops. Soil bulk density and porosity in the topsoil layer were more dependent on soil organic matter content than on agricultural practices used: in the moderate soil organic matter content compared with the low soil organic matter, bulk density was by 1.4 % lower, and porosity by 1.8 % higher.

ACKNOWLEDGEMENTS

The paper presents research findings, which have been obtained through long-term research programme “Productivity and Sustainability of Agricultural and Forest Soils” implemented by Lithuanian Research Centre for Agriculture and Forestry.

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AN ANALYSIS OF DROUGHT IN MAIN AGRICULTURAL AREAS FROM ROMANIA USING SPI AND RDI INDICATORS

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ABSTRACT

Romania has an agricultural capacity of approximately 14,7 million hectares, of which only 10 are used as arable land. In November 2008, an evaluation revealed that 6.8 million hectares are not used. Agriculture summed up about 6% of GDP in 2007, down from 12.6% in 2004.

Drought represents the effects of water demands unmet by the available resources. It is hardly to define drought as being a phenomenon due to the inexistence of a start time and an end time. In the south and south-eastern area of Romania, the complex agricultural drought is a climatic hazard phenomenon inducing the worst consequences ever occurred in agriculture. The strongest droughts affecting the crops in Romania are those occurring in the autumn and summer.

In the years with severe droughts, very small yields (below 1000kg/ha) were obtained, with a reduction of 60-70% of the productive potential of the areas, and sometimes the yields were totally damaged.

This paper will focus on an analysis of drought for the main agricultural areas of Romania, using several indicators computed with DrinC, a program less used in Romania, the analyzed period being 2006-2011. DrinC is a program which was developed to facilitate the procedure of the calculation of drought indices, which may be a complicated task especially in the case of the assessment of the spatial distribution of indices. Three drought indices can be calculated using DrinC: Deciles, SPI (Standardized Precipitation Index) and RDI (Reconnaissance Drought Index).

Key words: drought indicators, agriculture, SPI, RDI, deciles, DrinC software

INTRODUCTION

Drought is perhaps the most difficult event to be defined from the category of water scarcity events. Lack of water was defined, using a matrix, in 1982 by Vlachos. But the world has changed. 30 years later we improved this matrix which has reached now this new form.

Table 1 Water scarcity matrix

Typology of water scarcity		Time scale		
		Short term	Medium term	Long and very long term (even permanent)
Causes	Natural	Dryness	drought	Aridity
	Man made	Water shortage	Water stress	Water crisis

In this matrix, perhaps the most discussed phenomenon is drought. Drought was debated by many valuable researchers (as Wilhite, Palfay etc.) but it was never defined in an acceptable manner for all situations and by all scientists.

Due to the complexity of drought phenomenon, the existing and currently used definitions have been stated according to the field which they are addressed. There are some fairly general accepts according to which droughts originate from a deficiency of precipitation and result in a water shortage for some activity or for a specific target group. Drought definition should contain references to at least 4 elements [Dracup et al., 1980]: Nature of considered water scarcity; Considered period; Truncation level; Regional aspects.

It is this last element that makes almost impossible to find a universally accepted definition for drought. Palmer, in 1965, brings into question the definition of some key terms to drought. Thus, he defines drought as a meteorological phenomenon characterized by a prolonged and abnormal deficiency of moisture, respectively, to a more specific, as a time up to several months or even years, during which the supply of moisture at a specified climatological time fall below expectations. At a very general level of discussion, drought is a temporary recurrent phenomenon characterized by a reduction of rainfall in a given area (regional aspect) [Palmer, 1965].

The fact that drought is a recurrent phenomenon means that drought is a component of the climate cycle and thus we are talking about a normal phenomenon and not an extraordinary event. Rossi (2000) also defines drought as a recurring event. He defines drought as a recurrent natural phenomenon associated with a lack of available water resources in a large geographical area and extended over a significant period of time. The severity and intensity of drought can “push” this phenomenon, because of its impact, out of the “normal” events area [Rossi, 2000]

How can we define the “normal”? This term is very common in climatology being made permanent references to deviations from normal. It is very important in analyzing a phenomenon (drought or any other) to work with data sets of relevant size in order to have accuracy. It is indicated instead of using the term “normal” to use “averages”, this combination being much closer to the truth.

Following in the last years the common humans reaction, without scientific knowledge, I observed that drought means for them the effect of a long dog-days period (several months), without efficient precipitations for agriculture and in hydrology. In a popular conception, drought is acknowledged through a large number of results and effects.

There are two ways to define drought: from conceptual and from operation point of view. Conceptual definitions are limited to identifying the limits of this concept being formulated in general terms. Operational definitions go into depth of the problem because by their content are trying to reach at least the following aims: to identify the beginning of drought, the severity and the moment of drought cease in order to estimate the potential impact of drought, to analyze the frequency, to determine the probability of drought occurrence, the intensity, duration and spatial characteristics.

In 1987, Wilhite proposed, based on a study realized on 150 definitions of drought, the following classification: Meteorological drought; Agricultural drought; Hydrological drought; Socio-economic drought [Wilhite, 1987].

Tate and Gustard, in 2000, classified drought as it follow: Climatologically drought (deficit in precipitations); Agro-meteorological drought (deficit of water in soil); Hydrological drought (deficit regarding river flow); Hydrogeological drought (deficit of groundwater); Operational drought (the conflict between demands and available resources) [Tate and Gustard, 2000].

In 2012, in an excellent book about arid lands, R. Maliva and T. Missimer return to a drought classification on 7 directions as it follow: Meteorological drought; Climatological drought; Atmospheric drought; Agricultural drought; Hydrological drought; Socio-economic drought; Water management drought [Maliva & Missimer, 2012].

According to Sandu et al (2010), drought is a state of a biologic system in which the water requirements are below the optimal values, the supplying functions significantly vary, function of the growth and development stage [Sandu et al, 2010].

In Romania, drought affects 7.1 million ha, which represent 48% from the total agricultural land (RNIS, 2010). The most exposed and affected regions are the South, Southeast and East (<600 m³ water /hectare – extreme and severe pedological drought), regions where during the extremely droughty years average yields of various crops representing only 35-60 percent of the potential yields. An analysis of the last decades on annual mean air temperatures and annual precipitations indicated that annual mean air temperatures shown an increase of 0.5°C in the last 10 years while the same last decade highlighted a general decreasing trend in the annual precipitation.

In South-Western Romania became obvious the climatic tendency of passing from wet and half wet climate to half-wet and half-arid (even arid in some areas) climate. Corroborated with the missing or the degradation of hydroameliorative works, were created the necessary conditions for the appearance of water scarcity phenomenon in different forms and at different scales. In western and south western Romania, an important role in drought phenomenon appearance is played by vertisols which are spread on large surfaces. It deserves to be mentioned here and the problem of the surface drainage and drainage arrangements which worked intensive till few years ago and decrease dramatically the water table level in soils.

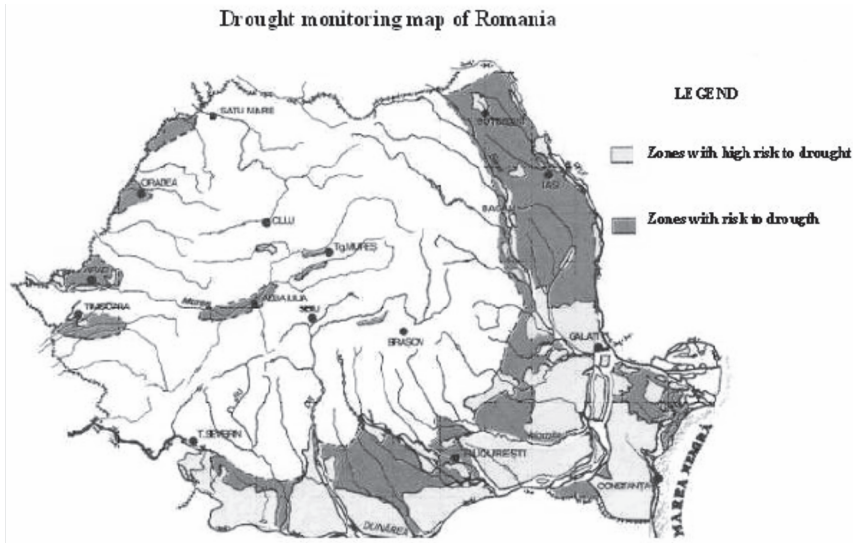


Figure 1 Drought risk map in Romania

METHODS

For this paper the author used data from statistical record (precipitations and temperature), data which was analyzed and interpreted with the help of DrinC program.

DrinC is a program which was developed to facilitate the procedure of the calculation of drought indices, which may be a complicated task especially in the case of the assessment of the spatial distribution of indices. Three drought indices can be calculated using DrinC: Deciles, SPI (Standardized Precipitation Index) and RDI (Reconnaissance Drought Index) [Tsakiris, 2005].

The input data are the annual or monthly precipitation for the calculation of Deciles and SPI, while potential evapotranspiration (PET) data are also required for the calculation of RDI. The user has an option to use temperature data in order to calculate PET by the Thornthwaite method.

The SPI was designed to quantify the precipitation deficit for multiple timescales. These timescales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow and reservoir storage reflect the longer-term precipitation anomalies. For these reasons, McKee and others (1993) originally calculated the SPI for 3-, 6-, 12-, 24- and 48-month timescales [WMO, 2012]

Standardized Precipitation Index (SPI) is a probability index that considers only precipitation. The SPI is an index based on the probability of recording a given amount of precipitation, and the probabilities are standardized so that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median, and half are above the median). The index is negative for drought, and positive for

wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive.

McKee and others (1993) used the classification system shown in the SPI value table below to define drought intensities resulting from the SPI. They also defined the criteria for a drought event for any of the timescales. A drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less. The event ends when the SPI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and an intensity for each month that the event continues. The positive sum of the SPI for all the months within a drought event can be termed the drought's "magnitude" [WMO, 2012].

The Reconnaissance Drought Index (RDI) is based both on the precipitation and on the potential evapotranspiration. RDI can be estimated for any period of time from one month to one year which allows an effective linkage of the RDI with the expected rainfed crop production and therefore with the anticipated losses in the agricultural sector due to the occurrence of drought [Tsakiris, 2005; Tigkas, 2008].

There are some advantages of RDI in comparison with SPI (it has a physical meaning, it can be estimated for any period of time, the estimated value is comprehensible etc.) and it can be directly linked to the climatic conditions of the region. RDI can be used for also climate instability conditions and to examine the effect of various changes of climatic factors on drought and desertification [Tsakiris, 2005; Tigkas, 2008].

RDI behaves in a similar manner as SPI so both indicators can be classified accordingly to the following table:

Table 1 RDI and SPI classification [5]

RDI or SPI value	Category
2 or more	Extremely wet
1.5 to 1.99	Severely wet
1 to 1.49	Moderately wet
0 to 0.99	Normal conditions- wet
-0.99 to 0	Normal conditions- dry
-1.49 to -1	Moderate drought
-1.99 to -1.5	Severe drought
-2 or less	Extreme drought

RESULTS

The first step consisted in calculating the values of potential evapotranspiration with the Thornthwaite method. With the help of these values and using temperatures and precipitations records for 6 locations from Romania (Timisoara, Calafat, Buzau, Galati) were calculated the SPI values (12-month) and respectively the RDI values (12-month, normalized and standardized), results which are presented in the next tables and figures.

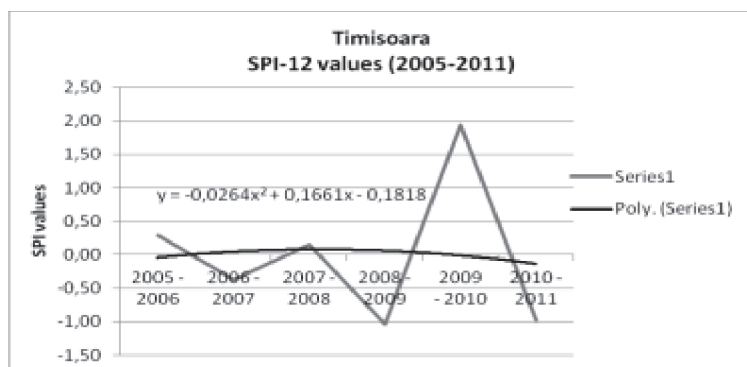


Figure 2 SPI-12 values for Timisoara (2005-2011)

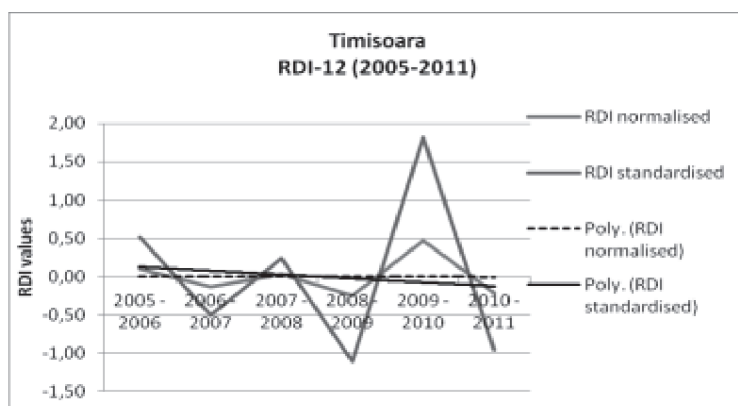


Figure 3 RDI-12 values for Timisoara (2005-2011)

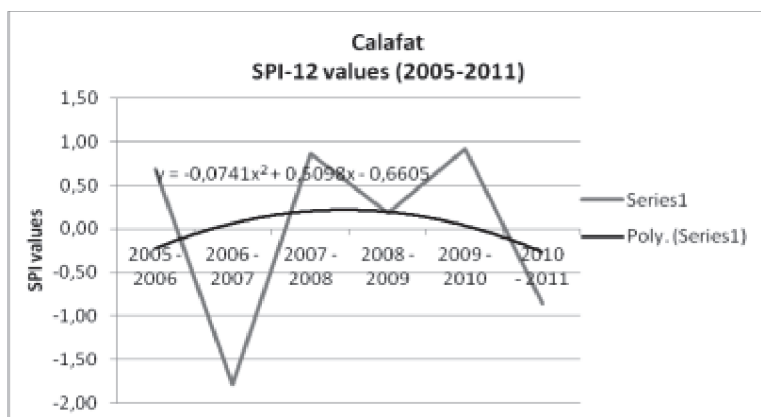


Figure 4 SPI-12 values for Calafat (2005-2011)

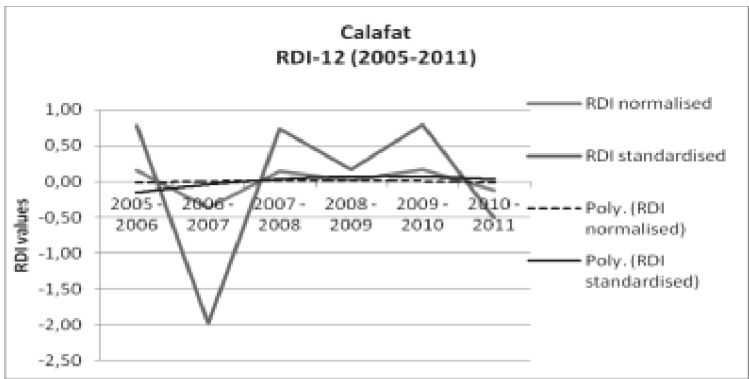


Figure 5 RDI-12 values for Calafat (2005-2011)

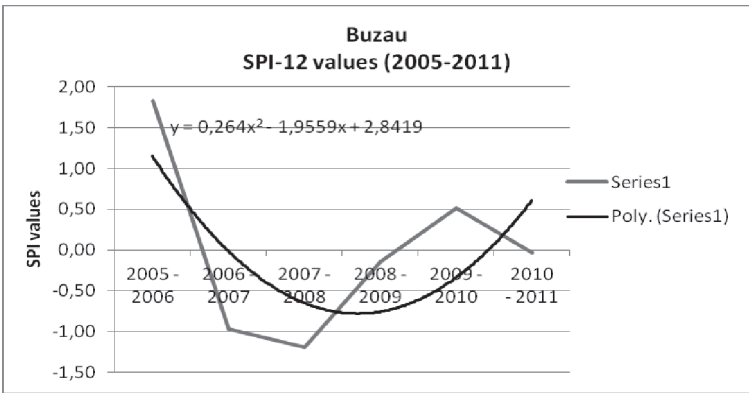


Figure 6 SPI-12 values for Buzau (2005-2011)

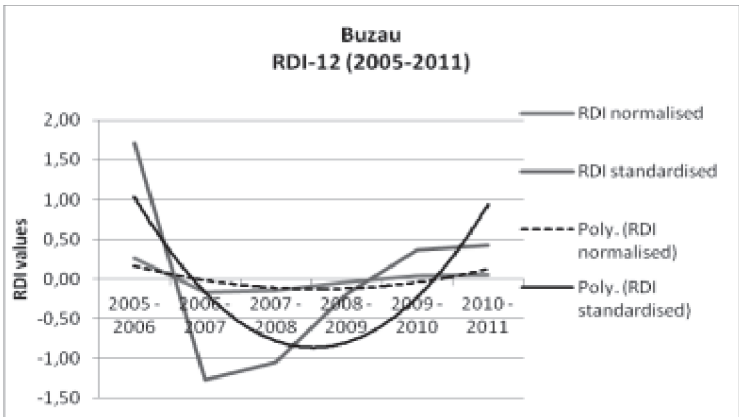


Figure 7 RDI-12 values for Buzau (2005-2011)

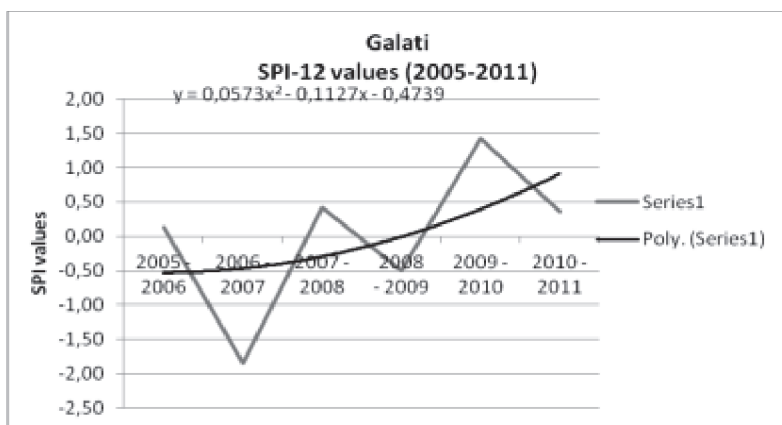


Figure 8 SPI-12 values for Galati (2005-2011)

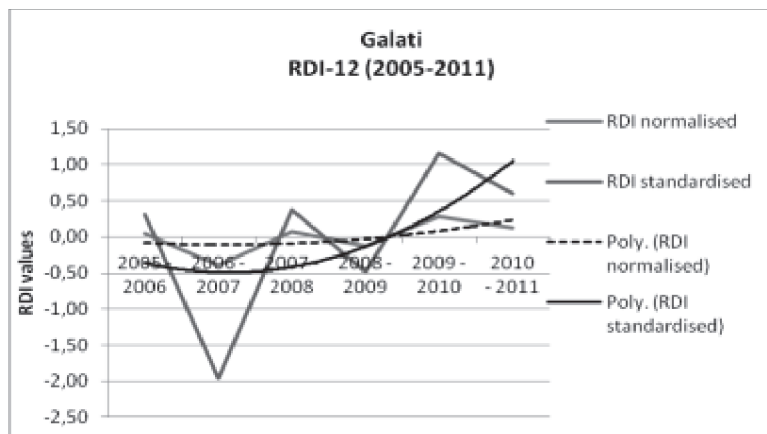


Figure 9 RDI-12 values for Galati (2005-2011)

Table 2 SPI-12 values calculated with DrinC for the analyzed areas

Location/ /Year	SPI-12 values					
	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011
Timisoara	0.29	-0.37	0.15	-1.03	1.93	-0.98
Calafat	0.69	-1.78	0.86	0.18	0.92	-0.86
Buzau	1.83	-0.97	-1.2	-0.14	0.52	-0.03
Galati	0.13	-1.84	0.41	-0.49	1.43	0.37

Table 3 RDI-12 values calculated with DrinC for the analyzed areas

		RDI-12 values					
Year		2005/06	2006/07	2007/08	2008/09	2009/10	2010/11
Timisoara	Normalised	0.1	-0.13	0.03	-0.24	0.47	-0.22
	Standardised	0.52	-0.51	0.24	-1.11	1.81	-0.95
Calafat	Normalised	0.16	-0.37	0.15	0.02	0.16	-0.12
	Standardised	0.78	-1.98	0.74	0.17	0.8	-0.51
Buzau	Normalised	0.26	-0.17	-0.15	-0.04	0.04	0.05
	Standardised	1.72	-1.27	-1.05	-0.19	0.36	0.43
Galati	Normalised	0.05	-0.39	0.07	-0.13	0.29	0.12
	Standardised	0.31	-1.96	0.37	-0.48	1.16	0.6

DISCUSSIONS

Drought is a common phenomenon especially for the south half of Romania. Analyzing only the temperatures and precipitation variations we can identify a drought gradient having a west-south west and west-east orientation. For a much more pertinent analysis, data on soil characteristics, relief, groundwater depth, vegetation cover etc. are needed.

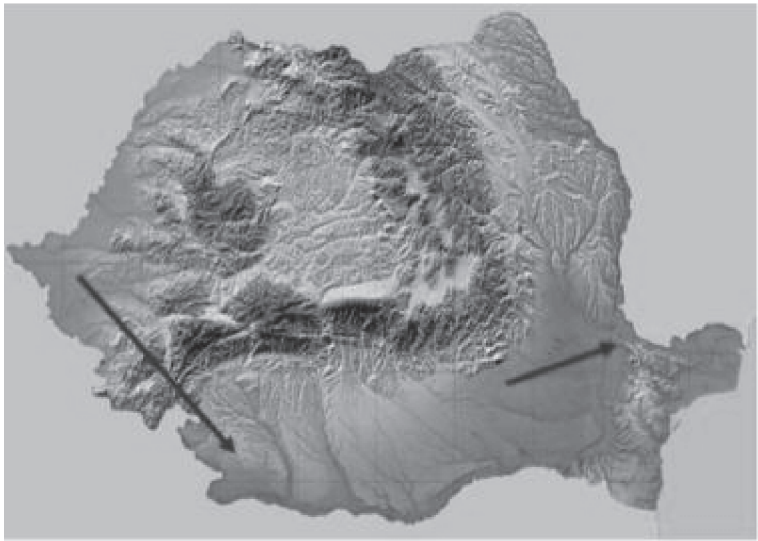


Figure 10 Drought gradients in Romania (2005-2011)

The period between 2005 and 2011 wasn't an extremely dry one having 2 very dry years while the others were dry, normal or light rainy according to the data provided by

Romanian National Institute of Statistics and the results obtained with DrinC. However, analyzing the previous graphs as well as the raw data used to have these graphs, the tendency is one to aridization with sudden alternations between dry and rainy years.

Drought centers are localized in west, south-west, south and south-east of Romania, covering plane areas with different exposures to winds and precipitations. Droughts severities are higher in south and east in comparison with the droughts from west.

A major problem is represented by major sudden drops of temperatures at the end of autumn and beginning of winter correlated with a high variability of precipitations. The drought identified at the conjunction between autumn and winter is very difficult to be countered. The agricultural years 2009-2010 and 2010-2011 presented this kind of problem and the effects were visible in agricultural productions. October and November were very warm months, with high temperatures for the end of autumn, and were followed by a very cold December sometimes without a snow cover which led to crops freezing.

According to a study provided by Mateescu et al (2012), the period between 2001 and 2012 was particularly droughty with severe impacts on agricultural productivity. The mean yield by ha decreased by more than 50% on the land surfaces where irrigation systems are absent. The Ministry of Agriculture and Rural Development provided some data which indicate as excessively droughty agricultural years 2011 and 2012 being strongly impacted about 5.9 million hectares. The most affected cultures included corn, wheat, barley, row barley, sun flower, rape and soya, the losses varying over different area

CONCLUSIONS

The problem of drought and mainly of drought effects in the analyzed areas should be addressed from 2 points of view. First of all, due to the regional features of drought phenomenon, a set of national and regional indicators in the field of meteorology and agro meteorology, climatology, hydrology and soil indicators should be consider to identify and analyze drought characteristics.

A second direction should focus on assuring a sustainable framework for agriculture by growing in each region the appropriate crops that have the largest benefit from the natural potential for agriculture. The natural potential can be evaluated through a carefully and detailed analysis of pedo-climatic conditions. The efficiency of crops is highly influenced by climate variability, accurate agro meteorological monitoring methods being needed. An accurate diagnose of agro meteorological conditions is an essential stage in the process of understanding the risks caused by weather events like drought and for adopting the so much necessary sustainable development actions.

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CLIMATE CHANGE IMPACT ON YIELD AND IRRIGATION DEMAND IN MAIZE PRODUCTION UNDER OPTIMUM IRRIGATION METHOD INCLUDING CO₂ FERTILIZATION EFFECT

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SUMMARY

DSSAT is a crop model used to quantify climate change impact on yield, dynamic in vegetation and possible adaptation measures in crop production. As it is working on a daily input data, the model is adequate for crop production in irrigated conditions. Earlier study for maize production, simulated in non irrigated conditions and irrigated conditions with 180 mm water supplied for a vegetation period, gave significantly lower and very significantly lower yield results. The subject of this paper was to estimate a yield and irrigation demands in maize production in expected climate conditions, while the irrigation is set on 50% available water in model. As an input data, it was used daily observed weather data from Republic Hydrometeorology Service of Serbia for current climate, out results from three global climate models (ECHAM, HadCM, NCAR) under A1B and A2 scenario, regionalized with Met & Roll weather generator for 2030 and 2050 year. Soil characteristics were collected for Novi Sad location, long-term field experimental data from Institute for Field and Vegetable Crops and genetic coefficients for medium season maize from DSSAT manual. All simulations were done under CO₂ concentration of 330 ppm and expected CO₂ concentration from IPCC Report from 2007. Simulations for 1971 - 2000 period gave high and stable yield through all thirty years, with irrigation demands from 120 to 460 mm, depending on precipitation amount and timing. For expected climate conditions, it was calculated relative change in yield and irrigation demand for 2030 and 2050 year in a comparison with 1971 – 2000 yield and irrigation demand. In future conditions under CO₂ concentration of 330 ppm, the yield was slightly lower in 2030 and significantly lower in 2050, with significantly higher irrigation demand. Simulations under expected CO₂ concentration from IPCC report, gave a high and stable yield in 2030 and 2050 year, with a very significantly higher irrigation demands.

Key words: *climate changes, CO₂ fertilization effect, DSSAT crop model, irrigation demand, maize, yield*

INTRODUCTION

Maize is an important field crop and one of the major strategy crops for every country. A maize in Serbia is mostly grown in non irrigated conditions. Only in field experiments is grown in irrigated conditions, where the irrigation amount is usually about 180 mm for vegetation period (Pejic et al., 2009). In earlier study, an impact of climate changes were quantified on maize yield in non irrigated and irrigated conditions with 180 mm water supplied for vegetation by DSSAT crop model (Jancic, 2013). In 2030 and 2050 the yield results were very significantly lower under non irrigated conditions. In maize production under 180 mm irrigated conditions, DSSAT simulation results showed a significantly lower yield in 2030 and very significantly lower in 2050. The projected decrease in yield was a consequence of expected lower precipitation during through whole vegetation period from April to September (15.5 lower in 2030 and 29.7% lower in 2050), especially in summer months June-July-August (- 22.7 in 2030 and - 42.4% in 2050), accompanied with high air temperatures, when maize production is most vulnerable on water stress and deficit in water. A climate data for 2030 and 2050 was projected with ECHAM A1B for 2030 and A2 scenario for 2050 year. The subject of this paper was to estimate climate change impact on maize yield and irrigation demands in expected conditions for 2030 and 2050 year, if the irrigation will be set on 50% available water. In such irrigation conditions maize will be grown under optimum water requirements, because maize is a field crop, which water requirements are between 50-60% of available water (Hoogenboom et al., 2012). Input data were collected for daily observed weather data from Republic Meteorology Service of Serbia (RHSS) for 1971 - 2000. For expected conditions, out results were assumed from global climate models ECHAM, HadCM, NCAR under A1B and A2 scenario for 2030 and 2050 year. The data were downscaled with Met & Roll weather generator (Lalic, personal communication). All simulations were done under CO₂ concentration of 330 ppm and under expected CO₂ concentrations from IPCC Report from 2007 year. Soil mechanical and chemical characteristics were assumed from Ciric, 2008. Agrotechnology data were collected from Institute for Field and Vegetable Crops long term experiment (Pejic et al, 2009) and genetic coefficients for medium season maize were given from DSSAT manual. It was calculate relative change in yield and irrigation demand for 2030 and 2050 in a comparison with 1971 – 2000 period. In the paper is presented: a) yield results for 1971-2000 period; b) irrigation demand results for 1971-2000; c) relative change in yield for 2030 and 2050 under CO₂ concentration of 330 ppm; d) relative change in yield for 2030 and 2050 under expected CO₂ concentration; e) irrigation demand for 2030 and 2050 under CO₂ concentration of 330 ppm; f) irrigation demand for 2030 and 2050 under expected CO₂ concentration.

MATERIAL AND METHOD

DSSAT 4.2 model is a crop model developed as a result of IBSNAT project (International Benchmark Sites Network for Agrotechnology Transfer project) to simulate biological crop demands and most effective use of current and expected soil and climate resources

(Tsuji et al., 1998). Model contains sub modules which describes atmosphere-soil-crop interaction.

Input data. Minimum data set has been defined 1984 and amended till 1988 (IBSNAT 1984; IBSNAT 1986; IBSNAT 1988; IBSNAT 1989). The data refers to meteorological and soil conditions, genetic coefficients and applied agro technology.

Meteorological conditions. The daily values of meteorological elements (maximum temperature, minimum temperature, precipitation, solar radiation, evaporation, wind speed) were used in this paper to describe the climate conditions on chosen location. These values were observed on weather station Rimski Sancevi in the period 1971–2000, which are obtained from RHSS. For description of expected climate conditions, there were used three climate models: (a) HadCM3 (Gordon et al., 2000), (b) ECHAM5 (Roeckner et al., 2003) and (c) NCAR-PCM (Washington et al., 2000). These models had two scenarios „pessimistic“ (SRES-A2) and „optimistic“ (SRES-A1B) for greenhouse gas emission for 2030 and 2050. The data assimilated from climate models may be used after its downscaling. This is the process of meteorological data regionalization in time and space. In this paper downscaling was done by Met & Roll weather generator (Dubrovsky, 1996; Dubrovsky, 1997) (Lalic, personal communication). At the first, simulations were done for CO₂ concentration of 330 ppm. In the second step the CO₂ concentration was set for values from IPCC Report from 2007 year. (Tab. 1)

Table 1 CO₂ concentrations from IPCC Report, 2007.

CO ₂ concentration (ppm)	
Referent period (1971-2000)	330
A1B scenario	
2030	454
2050	532
A2 scenario	
2030	451
2050	532

Soil conditions. The soil type, its mechanical and chemical characteristics were assimilated from Ćirić V. 2008. The values used in simulations are presented in Table 2.

Table 2 Physical and chemical characteristics of chernozem (Ćirić, 2008),
Particles content (%)

Depth (cm)	Coarse sand	Fine sand	Silt	Clay	Texture class	pH in H ₂ O	Org. C (%)	Nitrate (%)
0-30	0.80	35.95	35.76	27.49	Loamy clay	6.96	1.51	0.19
30-53	1.33	37.81	34.31	26.55	Loamy clay	7.97	0.98	0.15
53-88	10.73	44.21	28.30	16.75	Clay loam	8.28	0.69	0.10

Agrotechnics. The experimental field was managed at the Institute of Field and Vegetable Crops in Novi Sad in a nine-year period (Pejic et al., 2009). In the first experimental year, the sowing was performed on April 20, 1997 with NSSC 640 medium season maize variety. In this trial NSSC 640 was sown on 35 m² field area, in block system in rows with density of 5.7 plants/m² (57.143 plants/ha), on 5 cm depth at 70 cm distance between rows and 25 cm between plants in a row. Mineral fertilizers were applied in fall (135 kg/ha of N, 135 kg/ha of P and 175 kg/ha of K) and spring (46 kg/ha of N with urea). Standard agronomic practices for maize growing were applied. The experimental aim was to test sprinkler irrigation method and its effect on maize yield, with 180 mm of water supplied per vegetation period. The yield values differences between rainfed and irrigated maize field were monitored.

Five genetic coefficients were defined in maize simulations (Tab. 3). These coefficients are necessary input data because they describe varieties phenological characteristics. They were given calculating the temperature sum for each vegetation phenophase (Ritchie et al., 1993).

Genetic coefficients were assimilated from DSSAT 4.0 crop model for medium season maize, as NSSC 640.

Table 3 Genetic coefficients for medium season maize

Genetic coefficients	Values
Thermal time from seedling emergence to the end of the juvenile stage (degree days above the base temperature of 8°C in the juvenile stage) (P1)	220.0 °C
Photoperiod sensitivity associated with delayed growth under the unfavourable long-daylight condition (P2)	0.400
Thermal time from silking to physiological maturity in degree days above the base temperature of 8°C in mature stage (P5)	980.0 °C
Potential maximum number of kernels per plant (G2)	800.0 kernel/ear
Kernel filling rate under optimum conditions (G3)	8.50 kernel/day
Interval in thermal time between successive leaf tip appearances in degree days above the base temperature of 8°C (PHINT)	38.90

On the base of genetic coefficients, environmental conditions and field experiment data, crop model was calibrated for non irrigated and irrigated maize production with 180 mm water supplied per vegetation (Jancic, 2013).

RESULTS AND DISCUSSION

Calibration and validation

Calibration and validation model were done for medium season maize NSSC 640 on the basis of experimental results from the Institute for Field and Vegetable Crops. In non

irrigated conditions relative deviation between simulated and observed yield was 37.1%. The highest (relative) deviation was for 2000, 2002, 2003 and 2004 year in which the number of dry days were above long-term average in growing season. This significant difference between simulated and observed yield values is a consequence of model inability to simulate the plant reaction to stress in extreme conditions, such as high variations in daily air temperature and precipitation sum in short time intervals (Lalić et al., 2011). If the yield values in dry years were excluded from calculation (calibration), the relative deviation in yield will be 4% in rainfed conditions. In irrigated conditions with 180 mm water added per vegetation relative deviation between simulated and observed yield was 8.8% Jancic, 2013.

Current conditions 1971-2000 period

Simulated average yield results (t/ha) for 1971 - 2000 period under 50% available water are presented in Figure 1. The average yield values for Novi Sad location were high and stable through all thirty years. Only one year the yield was under 12.5 t/ha (12.43 t/ha) what was also characterized as a high yield result.

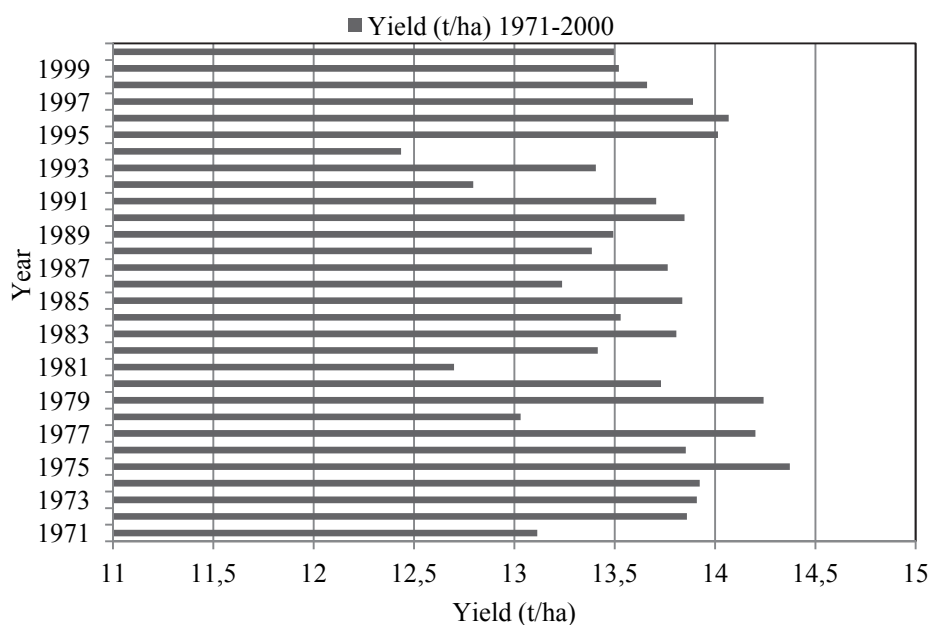


Fig. 1 Simulated maize yield (t/ha) under 50% AW for 1971 - 2000 period

Simulated irrigation demands for 1971 - 2000 period are presented in Figure 2. The irrigation amount for vegetation period was from 120 to 460 mm, which strongly depends on precipitation amount and timing. In years, in which precipitation was very low the irrigation demand was high, as seen in 2000 year (Fig. 2).

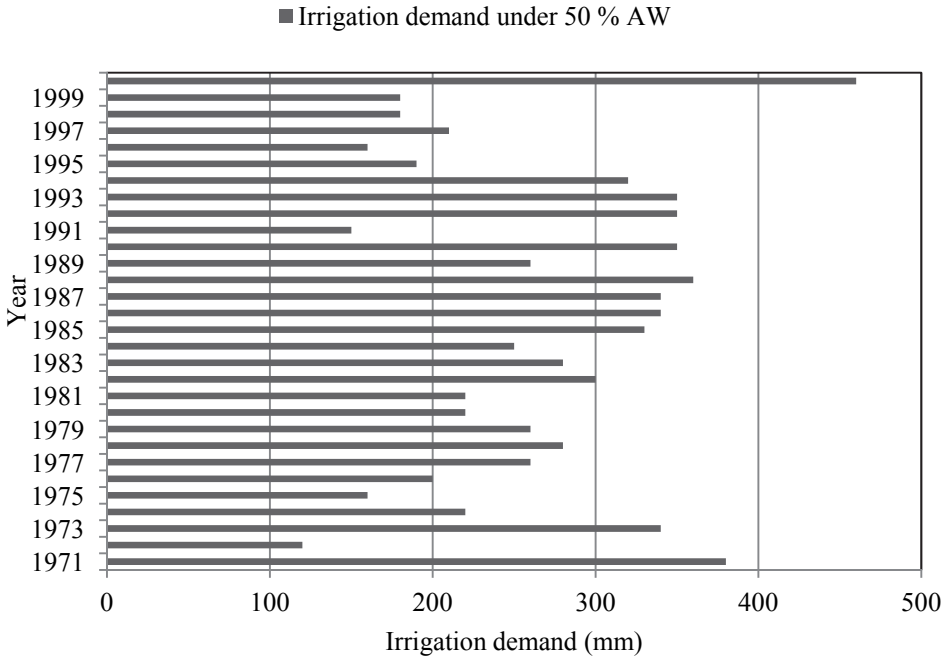


Fig. 2 Simulated irrigation demands for 1971 - 2000 period

Future conditions 2030 and 2050 year

The changes in yield under CO₂ concentration of 330 ppm showed lower yield in 2030 from 5 to 14% and 13 to 25% in 2050 year for three climate models and two scenarios. The lowest change in yield was projected by HadCM and highest with NCAR model. There were no differences between scenario results. A decrease in yield results was a consequence of higher air temperatures in June-July-August period (1.3 °C higher in 2030 and 2.9 °C higher in 2050) and especially predicted more tropical days (days with T_{max} > 30 °C) during summer months June-July-August (5 days more in June, 12 days more in July and 10 days more in August in 2050), which impacts on heat stress in maize production. When air temperatures are much higher the effective temperature sums above 10 °C are also higher, which impacts on shorter vegetation period, especially during grain filling and directly lower yield.

The changes in yield under expected CO₂ concentration from IPCC Report, 2007 are presented in Tab. 5. DSSAT results for 2030 and 2050 shown no changes in yield when irrigation requirements were set on 50% available water under expected CO₂ concentration. There were no differences between climate model results and between scenarios results for one integration period. It is concluded that higher CO₂ concentration had positive impact on yield in climate change conditions.

Table 4 Relative change in yield (%) under 50 % available water for three global climate models under two scenarios in 2030 and 2050 year ($\text{CO}_2 = 330$ ppm) (E-ECHAM, H-HadCM, N-NCAR)

Location	2030						2050					
	A1B			A2			A1B			A2		
	E	H	N	E	H	N	E	H	N	E	H	N
NS	-8	-12	-5	-10	-14	-6	-16	-21	-13	-19	-25	-18

Table 5 CO_2 fertilization effect on maize yield for medium season maize NSSC 640 on Rimski Sancevi for 2030 and 2050 year

Location	2030						2050					
	A1B			A2			A1B			A2		
	E	H	N	E	H	N	E	H	N	E	H	N
NS	0	-2	0	-1	-2	0	-2	-4	-2	-3	-6	-3

Irrigation demand results in 2030 and 2050 year

The irrigation demands under CO_2 concentration of 330 ppm showed significantly higher irrigation requirements from 10 to 20% in 2030 and from 16 to 32% in 2050 year (Tab. 6). The highest change gave ECHAM model under A2 scenario for both integration periods. The lowest change was projected with NCAR model under A1B scenario. There were no significant differences between scenario results for one period and slightly differences between ECHAM, HadCM and NCAR model. In 2050 year the irrigation demands were very significantly higher. A much higher irrigation demand was a consequence of predicted lower precipitation, especially during JJA period.

Table 6 Relative change in irrigation water demands in 2030 and 2050 using three GCMs (ECHAM, HadCM, NCAR) under two scenarios (A1B, A2) from the Special Report on Emissions Scenarios $\text{CO}_2 = 330$ PPM

Location	2030						2050					
	A1B			A2			A1B			A2		
	E	H	N	E	H	N	E	H	N	E	H	N
NS	17	13	10	20	15	11	28	21	16	32	25	18

In 2030 and 2050 year there were no differences between relative change in irrigation demand results under CO_2 of 330 ppm and under expected CO_2 concentration Tab. 7.

Table 7 Relative change in irrigation water demands in 2030 and 2050 using three GCMs (ECHAM, HadCM, NCAR) under two scenarios (A1B, A2) from the Special Report on Emissions Scenarios for twelve locations CO₂ =454 451 PPM; 532PPM concentration

Location	2030						2050					
	A1B			A2			A1B			A2		
	E	H	N	E	H	N	E	H	N	E	H	N
NS	15	10	7	17	12	9	24	18	13	28	22	15

CONCLUSION

In 1971-2000 the yield was high and stable through all thirty analysed years under 50% available water conditions. Irrigation demand was from 120 mm to very high 460 mm in 2000 year. Irrigation demand strongly depend on precipitation amount and timing.

In future climate conditions, under CO₂ concentration of 330 ppm, the yield results are expected to be from 5 to 14% lower in 2030 and 13 to 25% lower in 2050.

Under expected CO₂ concentration from IPCC Report 2007, the simulations predicted no changes in yield in 2030 and slightly lower yield in 2050 with HadCM model.

CO₂ fertilization effect was positive on yield. There were no changes in yield between 1971-2000 and 2030, 2050 year.

The irrigation demand under CO₂ concentration of 330 ppm in 2030 showed significantly higher irrigation requirements from 10 to 20% and very significantly higher in 2050 from 16 to 32%.

In a comparison of irrigation demand under CO₂ concentration of 330 ppm and expected CO₂ concentration from IPCC 2007, there were no differences between results.

CO₂ fertilization had no impact on irrigation demand in future conditions.

The yield analyses for 2030 and 2050 showed high and stable yield under optimum irrigation method, but irrigation demands were significantly higher. In further studies there is a need to calculate crop water productivity and cost effectiveness of irrigation method in maize production.

ACKNOWLEDGEMENT

The research described here was funded by the Serbian Ministry of Science and Technology under the project No. III 43007 „Research of climate changes and their impact on environment. Monitoring of the impact, adaptation and moderation“ for 2011-2014.

Author Milena Jancic is grateful Prof. Branislava Lalic for weather data downscaling with Met & Roll weather generator.

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SPRINKLER JET FLOW: CLASSICAL AND QUANTUM THERMAL-FLUID DYNAMICAL ASSESSMENT

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ABSTRACT

The present paper is aimed at analyzing the behaviour of water droplets travelling in air from the nozzle to the ground according to a traditional numerical and a quantum point of views. Considering a single-droplet system, an analytical model based on the Newtonian kinematics is here described, considering the most relevant parameters involved: droplet initial diameter, droplet initial velocity, water and air temperatures, diffusion coefficient of water in air, air relative humidity, environmental radiation and presence of wind. The effect of those parameters on water evaporation is hence discussed. Differently, when multi-droplet system is considered, the problem becomes even more complicated due to the difficulty of assessment of inter-droplet reciprocal affections and both a Newtonian description and a numeric implementation are definitely hard to obtain. An alternative to traditional approaches to treat the water droplet dynamics is the quantum approach, which is here introduced and pointed out in order to give an as full as possible description of the whole phenomenon. Such approach offers a more tight description of the microscopic phenomena that influence the evolution of the whole multi-droplet system.

Key words: sprinkler irrigation, water droplets, thermal fluid dynamics, classic and quantum mechanics, single and multi-droplet systems

INTRODUCTION

It is known that sprinkler irrigation, which is one of the most diffused irrigation practice, is affected by water losses consisting in droplet evaporation, evotranspiration and

groundwater losses. Among these, droplet evaporation is usually assumed to be the major source of water loss: a certain percentage of the total amount of water entering the irrigation system through the nozzle outlet, molecule by molecule evaporates in air before reaching the ground. The first approaches to treat the problem of water evaporation in agriculture were limited to practical experiences based on strictly case-dependent descriptions [1-7]. Unfortunately these case-bound process descriptions had been proving themselves to not be much reliable in discovering general laws for real phenomena and also many field studies reported conflicting results about droplet evaporation largely due to the limitations of traditional measurement methods [8].

To better assess the evaporation phenomenon it has been hence necessary to partially abandon case-dependent approaches introducing necessary simplifying hypotheses regarding the flight-event of water particles in order to describe the event under an analytical point of view. Examples of this “classical viewpoint” based on simplified kinematic analysis of droplets during the aerial are given in [3,5,6,9-11]. These simplified hypothesis mainly consist in considering just the Newtonian force applied to the droplet on one hand and in adopting the supposition of having some initial conditions of the system droplet-environment as constant, like, for example, the droplet shape on the other. Such picture can be considered sufficiently realistic only in presence of sufficient stable environmental conditions and in particular for droplets diameters not *too small* ($d > 0.5$ mm) [9]; the latter condition can be considered a first relevant result in droplets numerical modelling. A further step in literature was taken thanks to CFD (Computational Fluid Dynamics) implementation [22]. Within this ground, the CFD control volume code STAR-CCM+ describes droplet evaporation by means of an Eulerian-Lagrangian approach, in which a Lagrangian phase (water droplet) moves within a continuous Eulerian phase (air).

SINGLE DROPLET SYSTEM ANALYSIS

Thermal Fluid Dynamic Modelling

There are several possibilities to describe the flight-event associated to the system composed by in-flight droplet from the sprinkler nozzle to the ground in order to understand how the particles behave and how the evaporation process can be evaluated. At this regard a general analytical approach will be discussed, both in terms of kinematics and thermal-fluid dynamics [12]. According to Newton’s second law of Dynamics, the forces applied to the system composed by in-flight droplet from the sprinkler nozzle to the ground are weight, buoyancy and friction; the first two forces are directed vertically and opposite to each other, the latter is opposite to the relative droplet-air velocity:

$$\mathbf{F}_g = m\mathbf{g} \quad (1)$$

$$\mathbf{F}_b = -\rho_a \pi(d^3/6)\mathbf{g} \quad (2)$$

$$\mathbf{F}_g = -k\mathbf{v}_r \mathbf{v}_r \quad (3)$$

where m is the droplet mass, $\mathbf{g}$ the acceleration of gravity, ρ_a the air density, d the droplet diameter, k the friction coefficient, $\mathbf{v}_r = \mathbf{v} - \boldsymbol{\gamma}$ the relative droplet-air velocity, being $\mathbf{v}$ the droplet velocity vector $\boldsymbol{\gamma}$ the wind velocity vector; v_r is the relative droplet-air velocity module, with v_x, v_y, v_z and $\gamma_x, \gamma_y, \gamma_z$ the components of, respectively, the droplet velocity vector and the wind velocity vector. According to the forces just listed, the equations describing the motion of the water droplet in air are given by:

$$m \frac{d^2x}{dt^2} + k \mathbf{v}_r \left(\frac{dx}{dt} - \gamma_x \right) = 0 \quad (4)$$

$$m \frac{d^2y}{dt^2} + k \mathbf{v}_r \left(\frac{dy}{dt} - \gamma_y \right) = 0 \quad (5)$$

$$m \frac{d^2z}{dt^2} + k \mathbf{v}_r \left(\frac{dz}{dt} - \gamma_z \right) = -m_b \mathbf{g} \quad (6)$$

where m_b is the net droplet mass diminished by buoyancy effect. Written in the compact form, Eqs.(4) – (5) take the general equation form of the droplet trajectory:

$$m \frac{d^2\mathbf{Q}}{dt^2} + k \mathbf{v}_r \left(\frac{d\mathbf{Q}}{dt} - \boldsymbol{\gamma} \right) = -m_b \mathbf{g} \quad (7)$$

Note that the so called classic approach derives from the only use of the classical force $\mathbf{F}$ deriving from Eq. (7) so that:

$$m \frac{d^2\mathbf{Q}}{dt^2} = \mathbf{F} \quad (8)$$

Note that in certain applications the resultant force $\mathbf{F}$ does not include the presence of wind, which can be considered negligible. The reliability of the approach just shown depends, among other things, on the estimation of the friction coefficient $k = \frac{C_d \rho_a A_{cs}}{2}$, being A_{cs} the cross sectional area of the droplet and $C_d = f(\text{Re})$ the dimensionless friction factor [12-15].

Nevertheless the classical approach just discussed can be considered quite satisfying as kinematic description, the whole phenomenon of evaporation deserves further analysis to be better assessed. Besides the Newtonian force it is necessary to keep into account the time dependent decrease of mass as result of evaporation.

It is hence relevant to assess the amount of water in liquid form that step by step leaves the droplet and enters the surrounding atmosphere. The variation of mass can be written as:

$$\frac{dm}{dt} = h_m S M_w (C_v - C_s) \quad (9)$$

where h_m is the mass transfer convective coefficient, S is the droplet external surface, $M_w = 18.02 \text{ kg kmol}^{-1}$ is the molar mass of water, and C_v and C_s are, respectively, the

vapour concentration in undisturbed air and the vapour concentration in air at the droplet surface in the condition of saturated air. The first approximation to be made is to consider vapour like an ideal gas so that one may write: $C_v = \frac{p_v}{R_0 T_a}$ and $C_s = \frac{p_s(T_w)}{R_0 T_w}$, being $p_v = \varphi p_s(T_a)$ the vapour pressure within the system, p_s the saturation pressure of water (at air or water temperature), φ the relative humidity, and $R_0 = 8314 \text{ kmol}^{-1}\text{K}^{-1}$ the gas universal constant. In particular, for high values of Re , the mass transfer convective coefficient h_m can be obtained by using the Sherwood number Sh relation:

$$h_m = \frac{Sh D_{v-a}}{d} \quad (10)$$

where d is the droplet diameter and D_{v-a} is the diffusion coefficient of water in air. The Sherwood number Sh can be determined by using practical values for Reynolds number Re and Schmidt number Sc ($Sh = 2 + 0.6Re^{0.5}Sc^{0.33}$); for a more in-depth analysis see [12,13].

In addition to the mass transfer process from the droplet surface to the surrounding air, the droplet itself is interested also by several heat transfer processes during its aerial path. Such phenomena can be summarized by the following balance equation:

$$c_w m \frac{dT_w}{dt} = q_l + q_s + q_{sol} + q_f + q_{env} \quad (11)$$

where q_l is the latent heat transfer, q_s is the sensible heat transfer, q_{sol} is the solar radiation absorption, q_f is the frictional heat contribution, and q_{env} environmental radiation heat flux. The sum of all heat contributions creating a variation in water temperature dT_w/dt are associated to the heat of water $c_w m$. The latent heat transfer q_l is given by:

$$q_l = r \frac{dm}{dt} \quad (12)$$

where r is latent heat of evaporation. The sensible heat transfer process by which the droplet is interested during its aerial path can be easily approximated in terms of convective heat transfer:

$$q_s = hA(T_a - T_w) \quad (13)$$

The convective heat transfer h can be computed by using the Nusselt number relation $Nu = \frac{hd}{\lambda}$, being $\lambda = 0.026 \text{ Wm}^{-1}\text{K}^{-1}$ the thermal conductivity of air, with $Nu = 2 + 0.6Re^{0.5}Pr^{0.33}$, being Pr the Prandtl number. The solar radiation absorption is given by:

$$q_{sol} = I_{sol} \alpha A_{cs} \quad (14)$$

where I_{sol} is the solar irradiance depending on the locality and on the cloud cover, and the water absorptivity in relation to the solar radiation can be assumed as equal to $\alpha = 0.94$

[16]. As the friction force acts upon the water droplet, the frictional heat flux contribution can be considered as:

$$q_f = F_f v_r \quad (15)$$

where F_f is the friction force module and v_r is the relative air-droplet velocity. The solar radiation can be calculated as:

$$q_{env} = h_r A (T_a - T_w) \quad (16)$$

where $h_r = 4\sigma\epsilon_l \left(\frac{T_a + T_w}{2}\right)^3$ is the radioactive heat transfer coefficient, $\sigma = 5.67 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$ is the Stefan-Boltzmann constant, $\epsilon_l = 0.95$ is the droplet emissivity for long wavelength radiation [16]. However this last contribution has proved to be negligible as the difference between air temperature T_a and water temperature T_w consist just in a few degrees. The analytical processes just shown allow to describe the actual phenomenon with a certain accuracy, but depending on the chosen approximations of the parameters involved. The most relevant ones can be chosen as variables within the numerical simulation problem, while the other ones can be approximated or hold as constants. Often the droplet initial position and velocity are considered known, and thus fixed and hold constant at practical values. Different studies have followed such general approach during recent years highlighting a certain accordance in results even with some difference depending on the specific implemented model [3,4,9,10,12,17-22].

Numerical Results

As already stated the effect of the solar irradiance q_{sol} on the droplet evaporation proves to be negligible, neither the presence of wind, represented by the scalar field $\mathbf{y}$ affect the droplet evaporation significantly. Also, droplets characterized by small diameters are interested by strong mass reduction and generally diameter and evaporation are tied up by a quasi-exponential relation (Table 1).

Table 1 Evaporation rate M_{ev} [%] vs. initial diameter d_i [mm];
Fixed parameters: $v_i=30 \text{ m s}^{-1}$; $\varphi=0\%$; $D_{v-a}=0.3 \text{ cm}^2 \text{ s}^{-1}$; $T_{wi}=304 \text{ K}$; $T_a= 320 \text{ K}$

d_i [mm]	0.1	0.4	0.7	1.0	2.0	3.0	4.0	5.0	6.0
M_{ev} [%]	44.67	11.85	7.89	6.03	3.51	2.53	1.97	1.61	1.36

Differently, both air temperature T_a and droplet temperature T_w are characterized by a linear proportionality with respect to the evaporation rate (Tables 2,3). About the affection of the droplet initial velocity v_i on evaporation, it is evident how higher velocities produce higher evaporation (Table 4) and this is mainly due to the increasing effect of air friction at high velocities. Table 5 shows the effect of the relative humidity φ on the droplet evaporation, which decreases with the former. Note that for particularly high values of

humidity the saturation pressure p_s approaches lower values than the vapour pressure p_v causing water condensation on the external surface of the droplet (i.e. negative values for M_{ev}). For a full picture of the relation between saturation pressure p_s and vapour pressure p_v see [12].

Table 2 Evaporation rate M_{ev} [%] vs. air temperature T_a [°C].

Fixed parameters: $d_i = 1$ mm; $v_i = 30$ m s⁻¹; $\varphi = 0\%$; $D_{v-a} = 0.3$ cm² s⁻¹; $T_{wi} = 304$ K.

T_a [°C]	27	32	37	42	47
M_{ev} [%]	4.81	5.09	5.36	5.66	5.96

Table 3 Evaporation rate M_{ev} [%] vs. droplet initial temperature T_w [°C].

Fixed parameters: $d_i = 1$ mm; $v_i = 30$ m s⁻¹; $\varphi = 0\%$; $D_{v-a} = 0.3$ cm² s⁻¹; $T_a = 320$ K.

T_w [°C]	15	23	31	39	47
M_{ev} [%]	4.26	5.05	5.96	6.94	7.96

Table 4 Evaporation rate M_{ev} [%] vs. droplet initial velocity v_i [m s⁻¹].

Fixed parameters: $d_i = 1$ mm; $\varphi = 0\%$; $D_{v-a} = 0.3$ cm² s⁻¹; $T_{wi} = 304$ K; $T_a = 320$ K.

v_i [m s ⁻¹]	5	15	25	30
M_{ev} [%]	2.39	4.71	5.70	6.03

Table 5 Evaporation rate M_{ev} [%] vs. relative humidity φ [%];

Fixed parameters: $d_i = 1$ mm; $v_i = 30$ m s⁻¹; $D_{v-a} = 0.3$ cm² s⁻¹; $T_{wi} = 304$ K; $T_a = 320$ K.

φ [%]	0	10	20	50	70
M_{ev} [%]	5.96	4.74	3.63	0.87	-0.60

MULTI-DROPLET SYSTEM ANALYSIS: THE QUANTUM PICTURE

Quantum mechanics for multi-droplet systems

Besides the specific method chosen to perform numerical simulations and the parameters involved that can be arbitrary chosen, the challenge is to find reliable trends for water droplets able to approximate as much a possible the reality. In this way, one should generally face the kinematic analysis of a multi-droplet system, considering a sufficiently high number of droplets that compose the water jet, and the whole set of inter-droplets relations since the single droplet is, in a certain measure, influenced by other droplets in the vicinity. At this regard a reliable analytical picture of a system composed by N droplets is almost impossible to obtain using the classical tools of Newtonian kinematics as it fails in representing the mutual interactions between small particles, mainly consisting in electrical interactions between the hydrogen and the oxygen atoms of the water molecules. For this

reason during recent years the problem has been treated in a theoretic form adopting a quantum viewpoint in order to assess also the inter-droplets relations. Firstly, for a multi-particle system, one can pose [23]:

$$m_k \frac{d^2 \mathbf{Q}_k}{dt^2} = \nabla_k V \mathbf{Q} \quad (1 \leq k \leq N) \quad (17)$$

where m_k is the k -th droplet mass, V is a potential function accounting for time dependence and ∇_k is the 3-D gradient operator referred to the k -th particle.

As already cited, in classical studies the kinematic analysis is essentially based only on the traditional force applied within the droplet-environment system that is characterized by some peculiar conditions. However those *special* circumstances often limit the description of the real phenomenon that is even more complicated, especially when a system composed by several droplets is considered. At this regard an analytical study based on Eq.(17) is far from being achieved.

Considering also a quantum potential, one can pose [24,25]:

$$m_k \frac{d^2 \mathbf{Q}_k}{dt^2} = \nabla_k (V |V_{qu}^{\psi_t}) \mathbf{Q} \quad (18)$$

being V_{qu} the quantum potential that can be written as:

$$V_{qu} = - \sum_{j=1}^N \frac{\hbar^2}{2m_j} \frac{\nabla_j^2 |\psi|}{|\psi|} \quad (1 \leq j < k \leq N) \quad (19)$$

here $\hbar = 1.055 \times 10^{-34}$ J s is the Dirac constant. Note that if the quantum potential V_{qu} is not considered, the particle trajectory tends to the classical one. Also, since the quantum approach implies that the object of analyzed has both the nature of particle and wave, for each element of the multi-droplet system one may write the time-dependent Schroedinger's equation (TDSE):

$$D^2 \nabla^2 \psi(\mathbf{Q}, t) - \frac{1}{2} m v(\mathbf{x}, t) \psi(\mathbf{Q}, t) = -i D \left(\frac{\partial}{\partial t} \right) \psi(\mathbf{Q}, t) \quad (20)$$

where D is the diffusion coefficient, $\psi(\mathbf{Q}, t) = R(\mathbf{Q}, t) \cdot \exp[S(\mathbf{Q}, t)]$, R is the wave amplitude, S is the wave phase. Eq. (20) can be re-written in the form of continuity and Euler-type quantum fluid dynamic (QFD) equations with $\mathbf{v}(\mathbf{Q}, t)$ the 3-D velocity field, respectively [25,26]:

$$\frac{\partial}{\partial t} \rho(\mathbf{Q}, t) + \nabla[\rho(\mathbf{Q}, t) \cdot \mathbf{v}(\mathbf{Q}, t)] = 0 \quad (21)$$

$$\frac{\partial}{\partial t} \mathbf{v}(\mathbf{Q}, t) \equiv \left[\frac{\partial}{\partial t} + \mathbf{v}(\mathbf{Q}, t) \cdot \nabla \right] \mathbf{v}(\mathbf{Q}, t) = -\frac{1}{m} \nabla[V(\mathbf{Q}, t) + V_{qu}] \quad (22)$$

Eqs. (20) and (21) are the basis for the full comprehension and assessment of the multi-particle motion when both Newtonian and quantum potentials are considered. Although such equations applied to water droplets are intuitive appealing, analytical solutions are basically impossible to obtain, even if this attempt will not be abandoned in future. The quantum picture provided can help to obtain a complete modelling of the evaporation process since it shows a substantial formal similarity to the Newtonian approach characterized by a system of forces associated to the gradient of a potential.

Quantum mechanics within a Density Functional Framework (DFF)

The Euler type equation applied in this context has given birth to so-called QFD. To complete the topic the QFD equations in the configuration space are here reported. At this regard the basic variables involved are the N-particle density $\rho(\mathbf{Q}, t)$ and the configuration space current density $\mathbf{j}_k(\mathbf{Q}, t) = \rho(\mathbf{Q}, t) \mathbf{v}(\mathbf{Q}, t)$, as the DFF employs a partitioning of the particle-density and the current-density variables [27]. The DFF provides a single-particle based approach for the description of the motion of many-particle systems in 3-D space. Within this ground the continuity equation can be reformulated as:

$$\frac{\partial}{\partial t} \rho(\mathbf{Q}, t) + \nabla \cdot \mathbf{j}_k(\mathbf{Q}, t) = 0 \quad (23)$$

and the Euler equation as:

$$\frac{\partial}{\partial t} \mathbf{v}(\mathbf{Q}, t) = -\frac{e}{m} \left[\mathbf{E}_{\text{eff}}(\mathbf{Q}, t) + \frac{1}{c} \mathbf{v}(\mathbf{Q}, t) \times \mathbf{B}_{\text{eff}}(\mathbf{Q}, t) \right] - \frac{1}{m} \nabla [V_{\text{eff}}(\mathbf{Q}, t) + V_{\text{qu}}(\mathbf{Q}, t)] \quad (24)$$

where $\mathbf{E}_{\text{eff}}(\mathbf{Q}, t)$ and $\mathbf{B}_{\text{eff}}(\mathbf{Q}, t)$ are respectively the effective electric and magnetic field [27]. Note that the trajectory-dependent quantum potential can be now expressed as:

$$V_{\text{qu}_k}(\mathbf{Q}, t) = \frac{\hbar^2}{8m} \nabla \rho_k(\mathbf{Q}, t) \frac{\nabla \rho_k(\mathbf{Q}, t)}{\rho_k^2(\mathbf{Q}, t)} - \frac{\hbar^2}{4m} \frac{\nabla^2 \rho_k(\mathbf{Q}, t)}{\rho_k(\mathbf{Q}, t)} \quad (25)$$

The Euler equation (24) can be recast into the Navier-Stokes equation given by [28]:

$$\frac{\partial}{\partial t} \mathbf{j}_k(\mathbf{Q}, t) = -\frac{e}{m} \left[\rho_k(\mathbf{Q}, t) \mathbf{E}_{\text{eff}}(\mathbf{Q}, t) + \frac{1}{c} \mathbf{j}_k(\mathbf{Q}, t) \times \mathbf{B}_{\text{eff}}(\mathbf{Q}, t) \right] - \frac{1}{m} \rho_k(\mathbf{Q}, t) \nabla V_{\text{eff}}(\mathbf{Q}, t) + \nabla \mathbf{T}_k(\mathbf{Q}, t) \quad (26)$$

where $\mathbf{T}_k(\mathbf{Q}, t)$ represents the stress tensor expressed as:

$$\mathbf{T}_k(\mathbf{Q}, t) = \left(\frac{\hbar}{2m} \right)^2 \nabla \nabla \rho_k(\mathbf{Q}, t) + \frac{1}{\rho_k(\mathbf{Q}, t)} \left[\mathbf{j}_k(\mathbf{Q}, t) \mathbf{j}_k(\mathbf{Q}, t) - \left(\frac{\hbar}{2m} \right)^2 \nabla \rho_k(\mathbf{Q}, t) \rho_k(\mathbf{Q}, t) \right] \quad (27)$$

The stress tensor is due to the contributions of both the quantum potential $V_{\text{qu}}(\mathbf{Q}, t)$ and the current density of the k -th particle trajectory. The jet flow is featured as a mixture of N particles and each particle, described by Euler equation, is characterized by common

effective electric and magnetic fields, and by a trajectory-dependent quantum force of stress tensor [27]. The DFF represents a versatile tool for description of equilibrium as well as dynamical characteristics of the system. The basic picture is that of a multi-component fluid mixture moving in common effective electric and magnetic fields and component-specific quantum potentials.

CONCLUSIONS

The present work faced the challenge of putting together two kind of approaches: the thermal fluid dynamic approach, based on the Newtonian potential and the quantum picture, for which, respectively, the state-of-the-art is represented by the application of the former to a single-particle system and the latter to a multi-particle system. Although they may appear different, they actually adopt a similar form.

In order to limit water evaporation the thermal fluid dynamic approach helps to understand which parameters facilitate the evaporation and which not, trying to describe the evaporation process under a quantitative point of view and assessing the correct weight of each relevant parameter.

However when one faces a multi-droplet system the biggest complications arise from the study of mutual interactions among particles, which consist in the electrical interactions between the hydrogen and the oxygen atoms of the several water molecules that compose the water jet. With the aim to fully describe the phenomenon, the water droplet could be treated as a quantum object, characterised both by material particle and by wave nature. The TDSE are employed to study the physical processes occurring during the flight event and the parallel classic-quantum descriptions is achieved, both for single-droplet and for multi-droplet systems. The topic is completed with the introduction of DFF through which it is possible to recast the QFD equations into the configuration space, obtaining appealing form for both the quantum potential and Euler equation enriched in the form of Navier-Stokes equation.

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A METHOD TO IMPROVE THE SPRINKLER IRRIGATION UNIFORMITY IN FOREST NURSERIES

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ABSTRACT

The research was carried out in the Iarac forestry nursery in the Iuliu Moldovan Forest District during 2010-2012, on an alluvial soil (the vertical-gleyed subtype). The placement of the sample plots was carried out according to the parcel in two repetitions, and the surface of a parcel was 450 m².

The present paper displays the results obtained after the sprinkler irrigation, when we determined the quantity of water spread by the 6 sprinklers on a 15m-radius, placed on the direction of the cardinal points.

The purpose of the research was to observe the correlation between the qualitative work indexes of the sprinkling devices, by spreading a uniform quantity of water on the entire surface and the maintenance of an ecological balance of cultivation of the saplings in the forestry nursery.

In a close connection with the purpose stated, the paper also focuses on the study of the work indexes of the sprinklers used in forestry nurseries, among which the most important is the uniformity of sprinkling.

The main means used for the improvement of sprinkling uniformity are the following: the usage of sprinklers with a small radius of sprinkling, having correct pluviometric curves; the correct placement of sprinklers on the terrain, according to the schemes of work recommended; avoiding to water when the speed of the wind surpasses the speed limit established for the sprinklers used.

Another major source of non-uniformity of the watering through sprinkling is represented by the influence of the wind. The wind deforms the circular form of the surface sprinkled, which becomes a more or less normal ellipsis and a more or less flattened ellipsis, according to the uniformity and intensity of the wind.

Key words: *sprinkler, sprinkler irrigation, uniformity of sprinkling, qualitative indexes of the sprinkling.*

INTRODUCTION

The uniform distribution of the sprinkled water on the surface of the soil is a technical element of great importance in the choice of the type of sprinkler and watering schemes. The quality and load of watering, but also the production rate obtained through irrigation depend on a great extent to the modality of distribution of the water on the terrain.

Thus, the condition of a uniform distribution of the water on the terrain is determined with the aid of an index of sprinkling uniformity. The condition of a minimum loss of water through surface leaking and the condition that the watering does not worsen the properties of fertility of the soils, through the deterioration of the soil (the formation of the crust) or through erosion are determined with the aid of an index of uniformity.

The condition of a minimum loss of water through evaporation during watering is determined through the index of the fineness of the rain. The same index serves together with the index of intensity for the appreciation of watering from the point of view of the formation of the crust and of the mechanical effects of the water on the tissues of the irrigated plants. [1, 17]

At sprinkling, the uniformity of distribution of the irrigated water is sometimes quite reduced as a result of some causes: Uniform distribution of the height of the rain across the radius of sprinkling. Not even the most efficient sprinklers can distribute uniformly, and as a result the circular surface watered by a sprinkler has the form of a concentric zone more or less differentiated according to the characteristics and functioning state of the used sprinkler.

In order to diminish the negative effect of the wind and to improve the uniformity of the sprinkling, it would be good to reduce the distance between sprinklers on the wing of sprinkling according to the speed of the wind. [2, 18]

The height of the sprinkler at 0.50 m when the wind blows is more favourable than at 1.50 and the stability to wind of the jet increases together with the size of the nozzle. Uniformity of watering depends on the speed of the wind and its direction, and also on some technical characteristics of the sprinklers, height of placement, etc. [3, 19]

While modifying the schemes, we must take into consideration the speed of the wind at the height of the sprinkler. The wings are placed as possible perpendicularly on the dominant wind and the sprinklers at the height of 40-60 cm above the soil in order to avoid the turbulence of the wind which is formed immediately on the soil. [4, 20]

On the basis of the different indexes found in the specialty literature, we acknowledge the limit speed of the wind at 5m/s, bigger speeds being prohibitive for the sprinkling. At a wind speed of 1.5-5m/s, one needs special schemes of placement of the sprinklers. At wind

speeds less than 1.5m/s, the influence of the wind is considered to be insignificant for the uniformity of the sparkling. [5]

Knowing the technical elements of the watering (schemes of watering, intensity of the rain, duration of watering, fineness of the rain, uniformity of the sprinkling) creates the premises necessary for the application of a uniform watering, the correlation of the intensity of the rain with the speed of infiltration of the water in the soil, but also possibility of appreciation of the quality of watering. [6]

An ideal sprinkler must accomplish an intensity whose value grows continuously, with smaller values from the periphery of the jet towards the sprinkler. These types of sprinklers ensure a good uniformity of watering when the work schemes are established judiciously, according to the distribution of the intensity on the radius. [7]

The intensity and the uniformity of watering are in a large extent influenced by the work pressure and the nozzle used. Thus, when the sprinkler functions at a too low pressure, it produces too big drops and an un-uniform distribution of the water. When the pressure is too high, the jet of the sprinkler is pulverized in smaller drops which are distributed around the sprinkler. [8, 9, 10, 11]

Thus, the present research had as a purpose the study of the possibility of introducing in the exploitation other types of sprinklers, adaptable to the requirements of the cultures and soils in question. The scope of the paper is to analyse the water distribution in sprinkler block-diagrams.

METHODS

The research was carried out in the Iarac forestry nursery (figure 1) in the Iuliu Moldovan Forest District (Arad County Branch) during 2010-2012, on an alluvial soil (the vertical-gleyed subtype). At the time when the measurements were taken, the meteorological conditions were: temperature of 24° C; wind speed of 2 m/s; total nebulosity: 4; and relative humidity 49. The placement of the sample plots was carried out according to the “divided parcels method” in two repetitions, and the surface of a parcel was 450 m².



Figure 1 The placement of the Iarac nursery

The present paper displays the results obtained after the sprinkler irrigation, when we determined the quantity of water spread by the 6 sprinklers on a 15 m-radius, placed on the direction of the cardinal points. The determination of the uniformity of sparkling by measuring the quantity of water sprinkled, which is collected in pluviometers, placed after a certain rule on the watered surface. In the case of the determination of the uniformity of sprinkling of an isolated sprinkler, the pluviometers are placed at equal distances of 1-2 m, on a radius, in conditions of atmospheric calmness or on four radiuses, in a cross, if windy.

In the case of the determination of the uniformity of sprinkling under a wing of rain, it is necessary to use a greater number of pluviometers, placed on two perpendicular directions, under the form of a grid.

Thus, we can produce a regular geometrical platform, having the width equal with the distance between two neighboring sprinklers, and the length equal with the distance between the two neighboring wings of rain.

The graphic of the isohyets is made by uniting the points which have the same collected quantity of water in the pluviometers. With the circle watering, the isohyets appear under the form of a concentric curve. In order to determine the quantity of water distributed from the sprinkler to the surface of the soil, we placed pluviometers at each meter on two diagonals (cardinal points), until the distance of 15 m, thus registering the quantity of water distributed, in mm or l/m².

In order to synthesized more efficiently the data and to describe more accurately the intrinsic characteristics of the sample, we proceeded to the statistical processing with the aid of the KyPlot program.

Thus, we established two surfaces for the sampling of the observational data, in a rectangular form, with a 450 m² (30 x 15 m) surface, among which one was the witness sample –the un-irrigated soil, and the other surface suffered successive modifications through the sprinkler irrigation. At each surface, we sampled 60 primary data, placed on the direction of the cardinal points (N, S, E, W) for each of the six sprinklers henceforth abbreviated (A1...A6).

Radial basis function interpolation

Radial basis function (RBF) interpolation consists in finding the coefficients, $\lambda = (\lambda_1, \dots, \lambda_n)$, for a base of radial functions and the coefficients, $c = (c_1, \dots, c_l)$, for a set of fitting polynomial, $p = \{p_1, \dots, p_l\}$, so that this interpolation function $s(x)$ defined below. [13]

$$s(x) = p(x) + \sum_{i=1}^n \lambda_i \cdot \phi(|x - x_i|) \quad , \quad x \in R^n \quad (1)$$

has to pass through the values of definition

$$s(x_i) = y_i \quad , \quad i = \overline{1, n} \quad \text{and} \quad \sum_{j=1}^n \lambda_j \cdot p(x_j) = 0 \quad (2)$$

where $(x_i; y_i)$ are the coordinates of N known points.

The thin plate radial function, $\phi(r) = r^2 \cdot \ln(r)$, was chosen for the studied case. These conditions, under the matrix form, can be written the following form. [14]

$$\begin{pmatrix} R & P \\ P^T & 0 \end{pmatrix} \begin{pmatrix} \lambda \\ c \end{pmatrix} = \begin{pmatrix} Y \\ 0 \end{pmatrix} \quad (3)$$

where we have:

$$R_{i,j} = \phi(|x_i - x_j|), \quad P_{i,l} = p_l(x_i), \quad Y_i = y_i, \quad i, j = \overline{1, n}, \quad l = \overline{1, m}.$$

The generated equations system has the solution given by. [15]

$$c = \left[(P^T \cdot R^{-1} \cdot P)^{-1} \right] \cdot (P^T \cdot R^{-1} \cdot Y), \quad (4)$$

$$\lambda = (R^{-1} \cdot Y) - (R^{-1} \cdot P) \cdot [(P^T \cdot R^{-1} \cdot P)^{-1} \cdot (P^T \cdot R^{-1} \cdot Y)]$$

First step involves a 1D RBF interpolation of the radial distribution of the water density over five measured points (the last one is the same as the first). [16]

This kind of interpolation was done with a 1m radial resolution and 1deg. angle resolution (see Figure 2). The 3D representation of all radius and angle range RBF radial interpolation is presented in Figure 3.

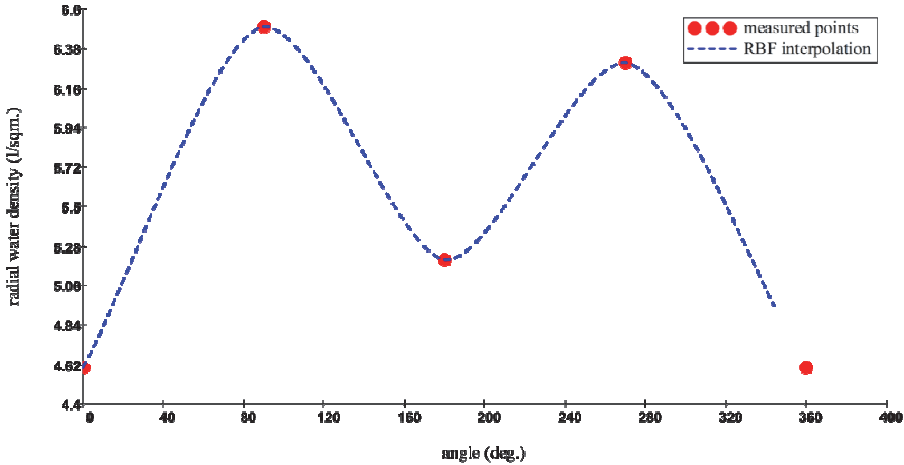


Figure 2 RBF 1D radial interpolation of the water density—example for one radius over the entire angle range

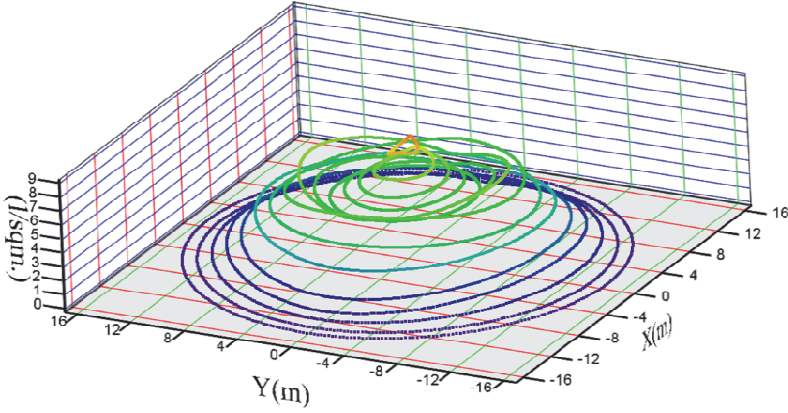


Figure 3 3D representation of all radius and angle range RBF radial interpolation of the water density distribution.

The block-diagram consists in a geometric multiplexing of multiple sprinkler water distribution, so we need to assess the water density distribution in 3D cartesian coordinates. The solution is to built up the 3D RBF cartesian interpolation (see Figure 4).

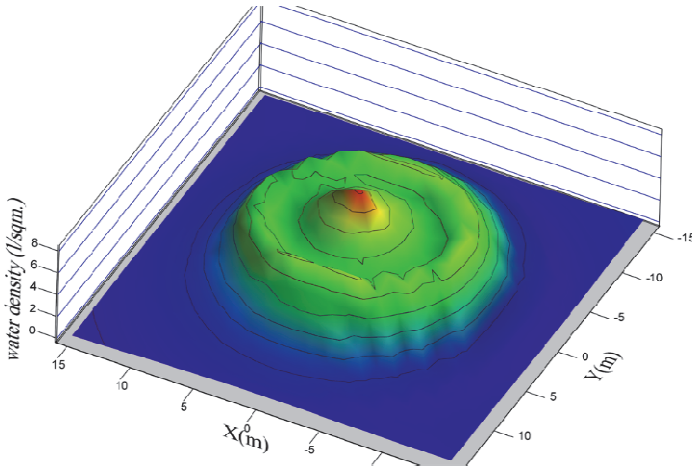


Figure 4 Result of 3D RBF cartesian interpolation of the water density distribution.

In Figures 5 (3D view) is presented cartesian interpolation of sprinklers sprayed water distribution 2 and 3 – real case. Figures 6 (3D view) presents cartesian interpolation of parabolic regression case of sprinklers sprayed water distribution 2 and 3. The triangle scheme used was not the echilateral one, but the 6.5m/7.5m isoscel triangle scheme in order to obtain a better uniformity.

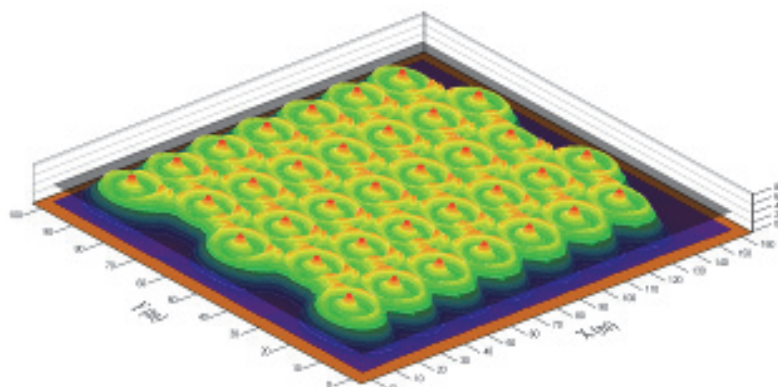


Figure 5 The 3D view of overlapping sprinklers wings (6.5m/7.5m) to a minimum quantity of 4.455l/m² of water inside the triangle display.

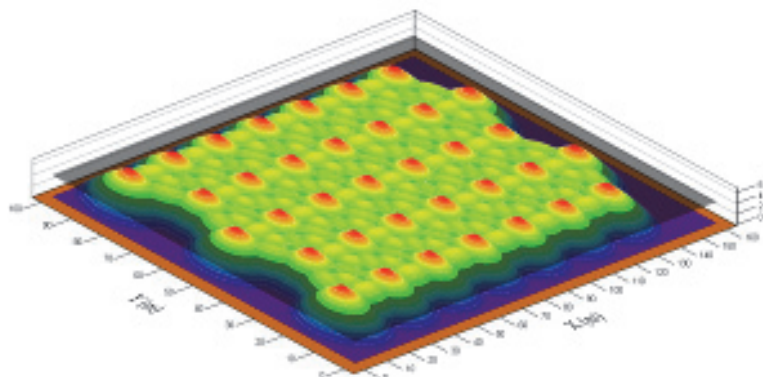


Figure 6 The 3D view of parabolic regression of sprinklers wings (6.5m/7.5m) to a minimum quantity of 4.461l/m² of water inside the triangle display.

RESULTS AND DISCUSSIONS

The quantity of water distributed by the six sprinklers included in the experiment is presented through average values in Table 1, at distances from m to m on a 15 m- radius, placed on the direction of the cardinal points.

Analysing the average values from the table below, we could observe the presence of some optimal values of the water accumulated in pluviometers, after the sprinkling, up to an 8m-distance; on this radius, the quantity of water accumulated presents quite big variances because of the speed of the wind or the functioning of the sprinkler.

This is particularly important because it provides information about the optimal distance between sprinklers in order to comply with the initial condition that the entire surface to distribute the same amount of water.

Table 1 Variance of some statistical indexes of the average values of sprinkling uniformity in connection with the cardinal points

Statistical indexes \ Cardinal points	North	East	South	West
Mean	3.94	3.35	3.28	3.19
S.E.M. (Average standard error)	0.60	0.67	0.57	0.54
Standard deviation	2.34	2.61	2.19	2.08
Coefficient of variation	0.59	0.78	0.67	0.65
Minimum	0.23	0.12	0.20	0.27
Maximum	7.50	7.00	6.88	7.40
The number of feature values (N)	15	15	15	15
Skewness	-0.46	-0.03	-0.15	0.38
Curtosis	-1.14	-1.64	-1.34	-0.59
Mean Deviation	2.12	2.52	2.05	1.74
Median	5.12	3.63	4.22	3.43
Range	7.27	6.88	6.68	7.13
Confidence Level(0,95)	1.29	1.45	1.21	1.15
Lower Confidence Limit	3.34	2.67	2.71	2.66
Upper Confidence Limit	4.55	4.02	3.84	3.73

In Figures 5 and 6, there is presented a horizontal plane that has been intersected at 4 l/m², as being the value for water distribution, in order to obtain the minimum humidity for the plants.

Then, the difference between the actual volume and the one calculated by parabolic regression has been done, thus, achieving the volume compared to the regressed one. (see Figures 7 and Figure 8).

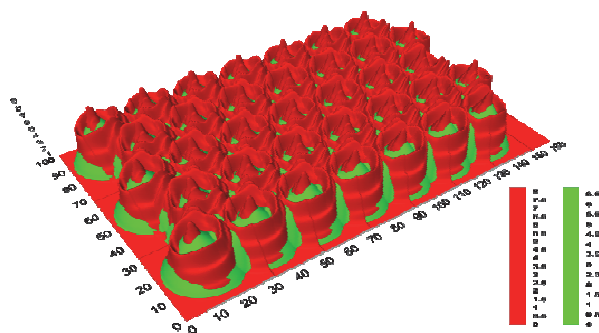


Figure 7 The 3D view of water density in real and parabolic regression cases of sprinklers wings (6.5m/7.5m).

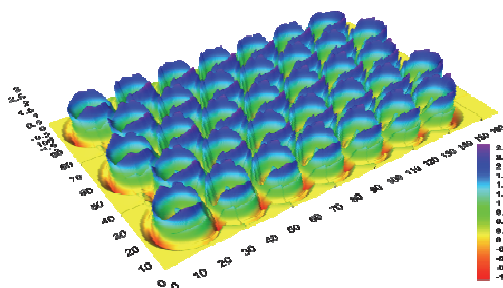


Figure 8 The 3D view of water density difference between real and parabolic regression of sprinklers wings (6.5m/7.5m).

Therewith, for these volumes their planar area was determined, in order to achieve the average water densities for the positive (above), negative (under) and total cases (Table 2).

Table 2 Differences between sprinkled water in the real and regressed cases

Water Volumes	(litres)	Planar areas	(sqm.)	Water density (l/sqm.)
Positive Volume [Cut]	10160.64	Positive Planar Area [Cut]	12277.57	0.828
Negative Volume [Fill]	1089.73	Negative Planar Area [Fill]	3657.49	0.298
Total Volume	70376.77	Total Planar Area	15935.06	4.416

When watering through aspersion, the uniformity of distribution of the water for irrigation is rather reduced because of some definite causes. One of the causes for the lack of uniformity of the water on the irrigated terrain through sprinkling is the watering of the sprinklers on circular surfaces. For the integral coverage with rain of the terrain, the circular surfaces must overlap in a smaller or greater extent according to the distribution scheme of the sprinklers. In conditions of correct placement of sprinklers on the terrain, the surface watered twice varies between 15 and 33%.

Another cause which influences the uniformity of sprinkling is the functioning of a sprinkler. It is obvious that the water jet, even at the improved sprinklers cannot be distributed in an absolute uniformity on all its length. That is why the circular surface watered by a sprinkler appears, from the point of view of the uniformity of sprinkling, under some concentric zones, more or less differentiated according to the characteristics and functioning state of the sprinkler used.

With the sprinklers of lower quality, the water is distributed very non-uniformly across the jet, the largest quantity of water falling at the periphery of the circular surface, while around the sprinkler there are minimal quantities of water. By overlapping the circular surfaces, the non-uniformity of sprinkling is amplified even more particularly in the zones with the biggest quantities of sprinkled water.

At the improved sprinklers, small quantities of water are distributed at the periphery of the circular surfaces. Thus, by overlapping the circular surfaces, we could ameliorate the

uniformity of sprinkling. The uniformity of distribution of the sprinkler is best given with the aid of a pluviometric curve.

Another major source of non-uniformity of the watering through sprinkling is represented by the influence of the wind. The wind deforms the circular form of the surface sprinkled, which becomes a more or less normal ellipsis and a more or less flattened ellipsis, according to the uniformity and intensity of the wind.

The irrigation scheme specifies the distance between the wing sprinklers (d_1) and the distance between two successive positions of an irrigation wing (d_2). According to the d_1 and d_2 values and to the position of the sprinklers on two adjacent wings, irrigation schemes can be square, rectangular or triangular.

The simplest and most commonly used schemes are square and rectangular. The rectangular scheme is also recommended for areas where winds have an established direction, in which case it is advised that the long side of the rectangle be placed parallel to the direction of the wind. If the wind is parallel to the irrigation wing, the distance between irrigation wings will be reduced so as not to leave any dry surfaces. [10]

The triangular scheme supposes $d_1=d_2$, but the first sprinkler is placed alternatively at a distance of $d_1/2$ and d_1 on the irrigation wings. This layout is more complicated, so the triangular scheme is used on a small scale, although it does ensure a coefficient of uniformity greater than in the other two methods of installing sprinklers.

When establishing the irrigation schemes the d_1 and d_2 distances between the sprinklers will be chosen so that they represent 60–65% of the irrigated diameter. In windy conditions, the degree of overlapping will increase along with the wind speed, so as not to reduce the watering uniformity. [9]

The distance between the wing sprinklers and the irrigation wings determines the size of the irrigated surface from a certain position of the irrigation wing. This size is limited by the need to ensure the entire coverage of the terrain. Considering the circular surfaces irrigated by the sprinklers, which will overlap, and provided that the surfaces are minimal, without having any sections irrigated three times, the following situations occur:

In the specialized literature is referred to minimum amount of water sprayed crop's needs, ranging from 2-6 mm / h depending on soil texture and crop species. [12]

CONCLUSIONS

This method had higher accuracy in estimating irrigation uniformity parameters compared with conventional methods, as it considered all catch-cans' data and their positional information in estimating water depths on a two dimensional grid. Distribution maps of water depth could also be generated from a limited number of observation data points by interpolation. Spatial water and/or nutrient application distribution maps are often required in management and evaluation of sprinkler irrigation systems.

The average density of 4.16 l/m², for the entire wetted surface it can be notified from table 2, a density of 0.298 l/m² is prescribed as being below this average density in light colored areas in Figure 7 and negative density areas in Figure 8.

Nevertheless, the real water minimum density is 4.455 l/m^2 , which indicates that the areas with negative water density differences from the parabolic regression case do not have values below the minimum of 4 l/m^2 .

In the present state, irrigation must satisfy both the requirements to ensure increased productions, but also to comply with the conditions of environmental protection (the prevention of the processes of soil erosion, the deterioration of soil properties, and the drive of chemical fertilizers in the soil).

At trials, we established that the pressure losses on the lateral pipes lead to a situation in which the spraying radii are lower than the central sprinkler so that the scheme with an equilateral triangle may be compromised if the pressure losses are not reduced at the lateral sprinklers.

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STANJE NA PODROČJU KMETIJSKIH TRAKTORJEV V SLOVENIJI

TOMAŽ POJE

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IZVLEČEK

V prispevku smo analizirali podatke o registriranih traktorjih v Sloveniji. Konec leta 2013 je bilo registriranih 100.965 traktorjev. V letu 2013 je bila povprečna moč novih traktorjev v Sloveniji 61,4 kW. V zadnjih letih ni več naraščanja števila traktorjev z močjo med 60 in 80 kW ter kategorija nad 80 kW. V letu 2013 so bili registrirani traktorji kategorije T1, T2 in T5. Največ - 19 % novih traktorjev je bilo registriranih na registrskem območju Ljubljana. Med lastniki novih traktorjev je bilo 650 pravnih oseb in 875 fizičnih oseb. Med fizičnimi osebami je 91,5 % moških, 8,5 % pa je ženskih lastnic traktorjev. Največ lastnikov (29,9 %) pa je starih med 50 in 60 leti. Večina proizvajalcev izkorišča možnost prehodnega obdobja glede predpisanih stopenj emisij onesnaževal za nove traktorje.

Ključne besede: število traktorjev, moč traktorjev, novo registrirani traktorji, lastniki traktorjev, Slovenija

UVOD

Po ocenah Agrievolution Alliance (globalna zveza združenj proizvajalcev kmetijske tehnike) se je svetovni trg za kmetijske traktorje v letu 2013 povečal za 10 odstotkov na 2.150.000 enot. To visoko število prodanih novih traktorjev predstavlja velik korak v smeri povečanega mehaniziranja kmetij. Največji traktorski trg sta Indija in Kitajska. Na obeh trgih se je prodaja traktorjev v letu 2013 povečala za okoli 15 odstotkov oziroma na 619.000 in 445.000 traktorjev. Tretja država, ki je dosegli nov vrhunec prodaj traktorjev v letu 2013, je Brazilija, kjer so kupili več kot 65.000 traktorjev. Močnejši trendi prodaje traktorjev so se pokazali tudi v Severni Ameriki, Turčiji in na Japonskem. Evropski trg s 190.000 prodanimi traktorji se je ustalil v drugi polovici leta 2013, celotno leto pa je pokazalo rahlo povečanje števila prodanih traktorjev (www.cema-agri.org, 2014).

Slovenija ima dve pomembni podatkovni bazi o traktorjih. Za prvo skrbi Statistični urad Republike Slovenije (SURS), ki na vsakih 10 let izvede Popis kmetijstva. Druga podatkovna baza pa so podatki ustreznih Ministrstev za registrirana vozila (traktorje). Poje (2010, 2012) in Jejčič (2004) za Slovenijo na osnovi podatkovnih baz in izvedenih anket proučujeta stanje traktorjev v Sloveniji.

Po podatkih SURS (2014) je bilo 1. junija 2013 v Sloveniji 72.377 kmetijskih gospodarstev; vsa skupaj so gospodarila s 477.023 hektarji kmetijskih zemljišč v uporabi (KZU) in redila 399.349 glav velike živine (GVŽ). Od leta 2010 se je število kmetijskih gospodarstev zmanjšalo za približno 3 %. Vsako kmetijsko gospodarstvo je obdelovalo povprečno 6,6 hektarja kmetijskih zemljišč in redilo 5,5 glave velike živine ter za to porabilo povprečno 0,17 polnovredne delovne moči na hektar kmetijskih zemljišč v uporabi (0,21 polnovredne delovne moči na glavo velike živine). Kmetijska gospodarstva so gospodarila tudi s povprečno 5,2 hektarja gozda, 0,31 hektarja kmetijskih zemljišč, ki so bila neobdelana ali v zaraščanju, in s povprečno 0,26 hektarja nerodovitnih zemljišč (med ta spadajo tudi pozidana zemljišča in dvorišča kmetijskih gospodarstev).

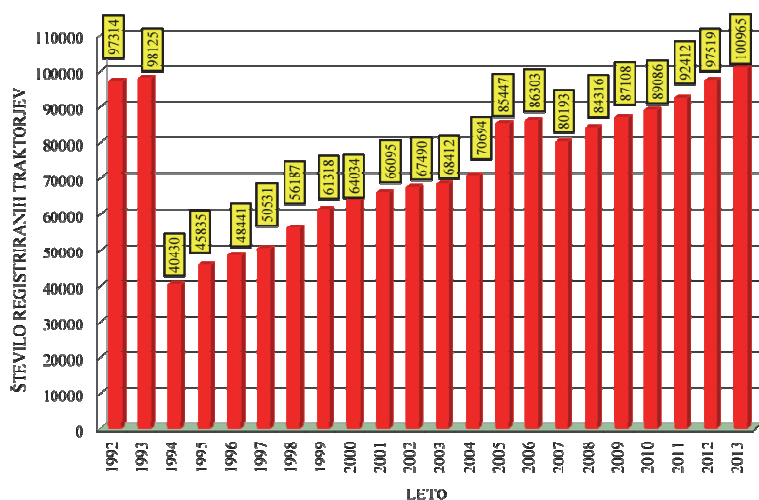
Namen prispevka je analiza razvojnih tendenc traktorskega parka v Sloveniji na osnovi podatkov o registriranih traktorjih.

METODIKA

Kot vir podatkov za analizo smo uporabili nov portal NIO (data.gov.si/nio/ alias nio.gov.si/nio/), ki je spletišče, ki je namenjeno objavi odprtih podatkov javnega sektorja. Portal NIO na enem mestu povezuje katalog elektronskih storitev in vzpostavlja centralno točko za objavo odprtih podatkov javnega sektorja. Portal NIO, je slovenski portal nacionalnega okvira interoperabilnosti in odprtih podatkov. Na tem portalu so tudi podatki o prvič registriranih vozilih v Sloveniji. Za te podatke sta odgovorni dve instituciji skrbnici in sicer Ministrstvo za infrastrukturo in prostor ter Ministrstvo za notranje zadeve, kjer so se te podatkovne baze nahajale do leta 2013. V prispevku analiziramo vse in na novo registrirane traktorje v izbranih letih s poudarkom na traktorjih iz leta 2013. V analizo zajeti podatki so obdelani z ustreznimi statističnimi analizami (opisna statistika).

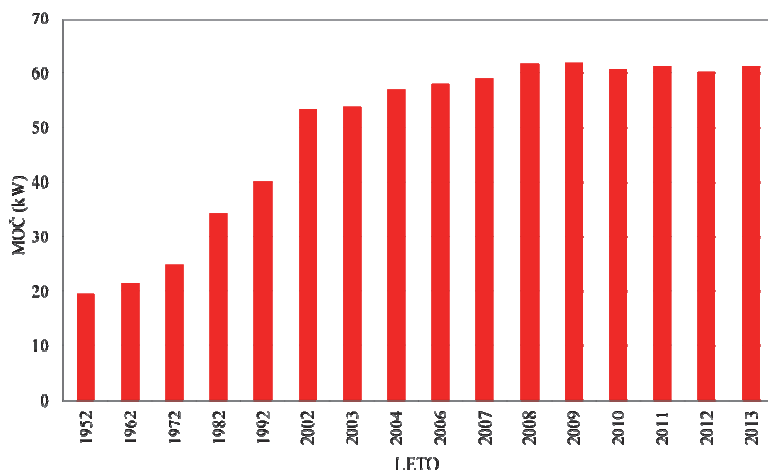
REZULTATI IN DISKUSIJA

Kmetijski inštitut Slovenije, Oddelek za kmetijsko tehniko in energetiko že vrsto let analizira podatke o registriranih traktorjih. Iz podatkovne baze o vseh registriranih vozilih v Sloveniji smo analizirali vse registrirane traktorje. V grafu 1 je prikazano število vseh registriranih traktorjev v Sloveniji za obdobje od leta 1992. V letu 1993 je bilo registriranih 98.125 traktorjev, naslednje leto pa se je število registriranih traktorjev zmanjšalo na 40.430 traktorjev zaradi prehoda na nove slovenske registrske tablice in takrat marsikdo ni več registriral traktorja. Po tem letu je število registriranih traktorjev počasi naraščalo, velik porast registriranih traktorjev pa je bil v letu 2005 ko je bilo v Sloveniji možno registrirati star traktor tudi brez podatkov o lastništvu. Konec leta 2013 je bilo registriranih 100.965 traktorjev. Po Popisu kmetijstva iz leta 2010 pa smo takrat imeli skoraj 101.756 traktorjev (SURS 2012).



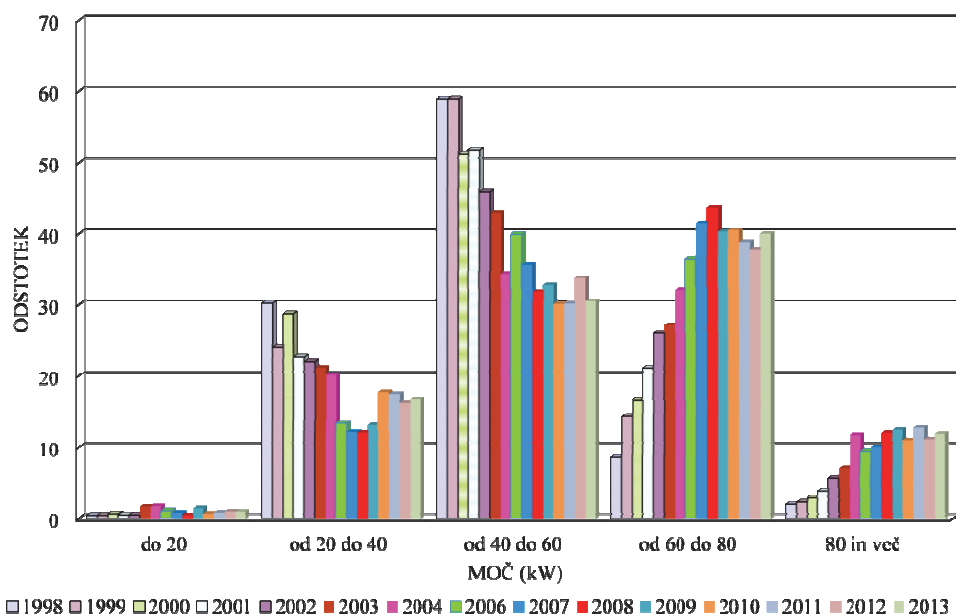
Graf 1 Registrirani traktorji u Sloveniji po letih
Graph 1 Number of registered tractors in Slovenia in period 1992-2013

Iz podatkov Ministrstva za notranje zadeve Republike Slovenije smo izračunali tudi povprečno moč registriranih traktorjev za posamezna leta. Iz grafa 2 je razvidno, kako se je povečevala moč po desetletjih in v nekaj zadnjih letih. Za traktorje izdelane in registrirane v letu 1952 je bila izračunana povprečna moč 19,6 kW. V letu 2013 je bila povprečna moč novih traktorjev v Sloveniji 61,4 kW.



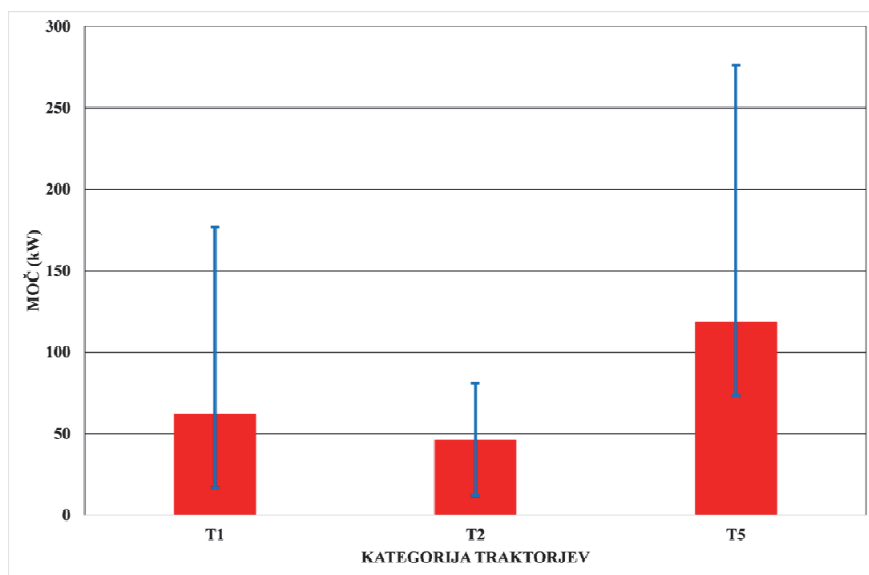
Graf 2 Porast moči traktorskih motorjev v Sloveniji v obdobju od 1952 do 2013
Graph 2 Increase of tractor's engine power in Slovenia in period 1952-2013

V grafu 3 so prikazani novi registrirani traktorji po kategorijah moči. Iz grafa je razvidno, da sta do leta 2008 rastli kategorija traktorjev z močjo motorja med 60 in 80 kW ter kategorija nad 80 kW. Po tem letu se je delež teh traktorjev stabiliziral. Kategoriji novih traktorjev z močjo med 30 in 40 kW ter med 40 in 60 kW sta na začetku obravnavanega obdobja upadali. Zadnja štiri obravnavana leta pa se je število traktorjev v teh dveh kategorijah stabiliziralo. V absolutnem številu ima kategorija traktorjev med 40 in 60 kW še vedno veliko število traktorjev (nad 30 %). Odstotek novih traktorjev v Sloveniji z močjo motorja pod 20 kW je majhen in relativno konstanten. Iz grafa se da razbrati tudi, da se v zadnjih letih kupci novih traktorjev odločajo bolj racionalno. Ne kupujejo več premočnih traktorjev, saj se posestna struktura v Sloveniji zelo počasi veča – povprečna velikost kmetije je 6,6 ha.



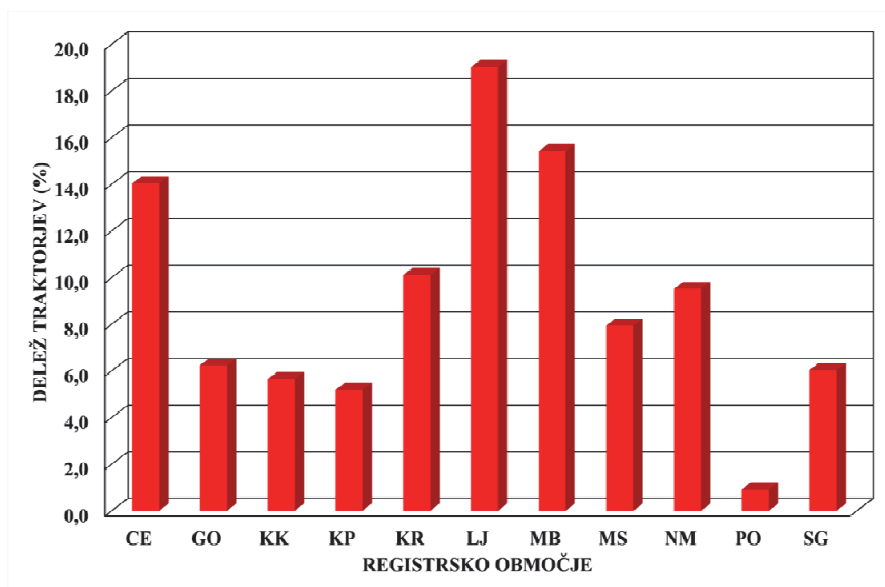
Graf 3 Novi traktorji registrirani v Sloveniji za zadnja leta po različnih kategorijah moči
Graph 3 Newly registered tractors according engine class in Slovenia in period 1998-2013

Analizirali smo tudi podatke o novih registriranih traktorjih v letu 2013. Glede na homologacijske zahteve imamo v Sloveniji 5 različnih vrst kolesnih traktorjev. Podatki iz grafa 4 nam kažejo, da so bili v letu 2013 registrirani traktorji kategorije T1, T2 in T5. Graf nam kaže povprečno moč traktorjev v posamezni kategoriji traktorjev (T1, T2 in T5) in minimalno ter maksimalno moč traktorja v teh posameznih kategorijah (ročaji). Kategorija T5 pomeni kolesne traktorje, ki gredo nad 40 km/h. Povprečna moč v tej kategoriji je 118,9 kW, maksimalna pa 276 kW. Na grafu 5 so prikazani delež novih registriranih traktorjev v letu 2013 po registrskih območjih. Graf 6 pa prikazuje dvajset upravnih enot v Sloveniji, kjer je bilo registriranih v letu 2013 največ traktorjev.



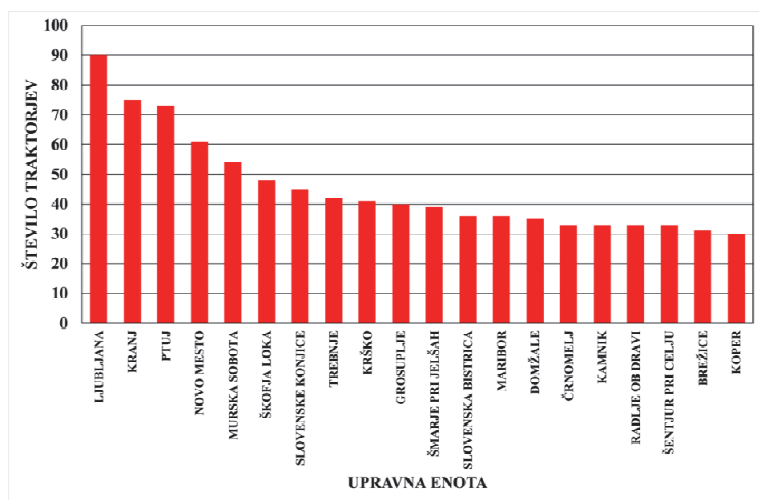
Graf 4 Povprečna moč (stolpci) in maksimalna ter minimalna moč (ročaji) za različne kategorije traktorjev

Graph 4 Average engine power and power range within different tractor's categories



Graf 5 Delež novih registriranih traktorjev v letu 2013 po registrskih območjih

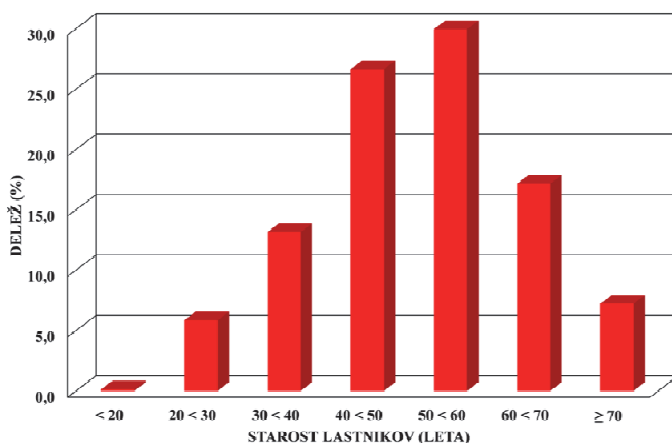
Graph 5 Distribution of newly registered tractors in 2013 according to registration areas



Graf 6 Število novih registriranih traktorjev glede na 20 upravnih enot, kjer je njihovo število največje.

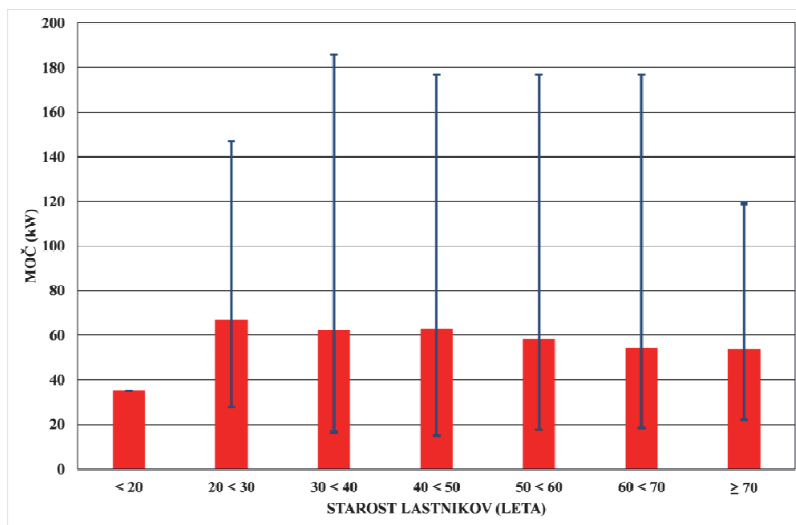
Graph 6 Distribution of newly registered tractors according to 20 local authorities

Analiza podatkov o novo registriranih traktorjih v letu 2013 nam pove, da je med lastniki novih traktorjev 650 pravnih oseb in 875 fizičnih oseb. Med fizičnimi osebami je 91,5 % moških, 8,5 % pa je ženskih lastnic traktorjev. Število pravnih oseb je veliko. Iz podatkov za vračilo trošarin za porabljeno gorivo v kmetijstvu je razvidno, da je pravnih oseb, ki delujejo v kmetijstvu, nekje do 90. Razlika v številu pravnih oseb pri registriranih traktorjih pa gre na račun podjetij, ki jih ustanovljajo na družinskih kmetijah zaradi drugih zahtev (davki itd.).



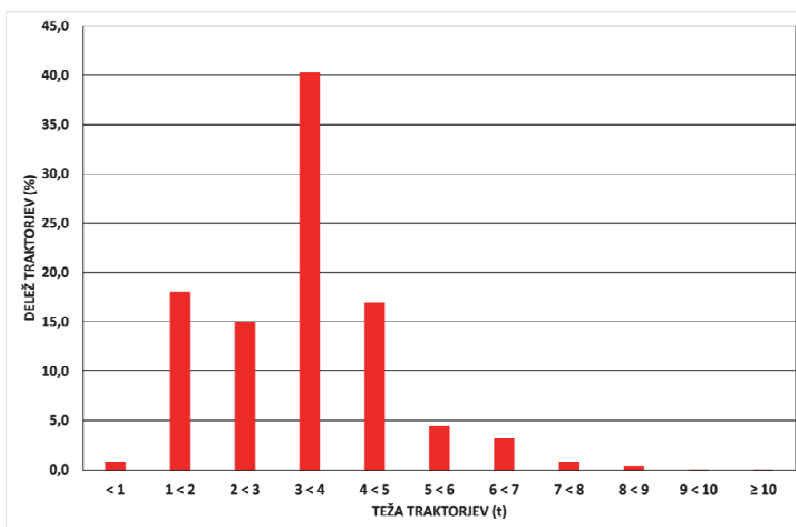
Graf 7 Delež lastnikov novih traktorjev v letu 2013 glede na starost
Graph 7 Distribution of newly bought tractors in 2013 according to owner's age

V letu 2013 je bilo 262 lastnikov starih med 50 in 60 letom (kar je največja starostna skupina z 29,9 % deležem). Sledi skupina lastnikov med 40 in 50 letom s 26,6 % deležem. Najmanj lastnikov novih traktorjev je med mladimi, do 20 let in v skupini med 20 in 30 leti.



Graf 8 Povprečna moč (stolpci) in maksimalna ter minimalna moč (ročaji) novih traktorjev v letu 2013 glede starosti lastnikov

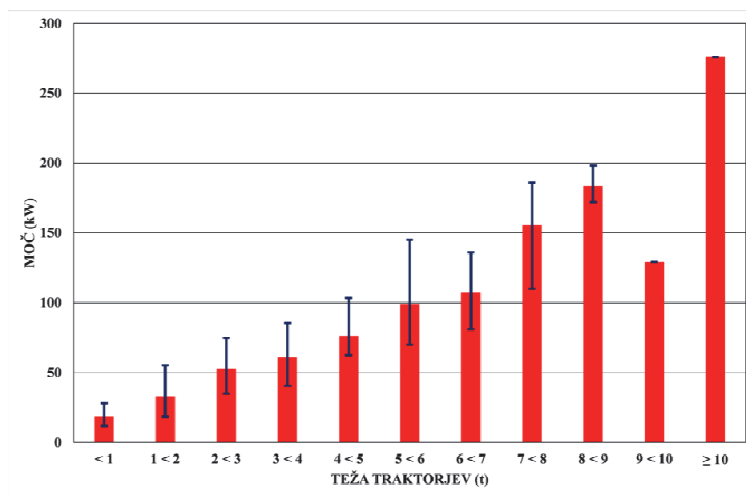
Graph 8 Average power and range of new bought tractors in 2013. according to owner's age



Graf 9 Delež novih registriranih traktorjev v letu 2013 glede na njihovo maso

Graph 9 Distribution of newly registered tractors in 2013. according to its weight

Traktorji postajajo vedno težji, ravno tako pa tudi njihovi priključki. V letu 1952 so bili traktorji v povprečju težki 1.640 kg, v letu 2013 pa 3.358 kg. Najtežji traktor registriran v letu 2013 je imel kar 11.500 kg. Vedno večji in težji traktorji ter priključki imajo za posledico tudi večji negativen vpliv na tla. S prehodi traktorja in priključkov ter samovoznih strojev prihaja do neželenega tlačenja tal in s tem do povečane zbitosti tal pod kolesnicami. Zbita tla imajo spremenjene mehanske (fizikalne) lastnosti tal, posledično pa prihaja tudi do spremembe kemičnega in biološkega stanja tal kar vse skupaj vpliva na rastline, ki jih pridelujemo.



Graf 10 Povprečna moč (stolpci) in maksimalna ter minimalna moč (ročaji) traktorjev glede na težo traktorjev

Graph 10 Average tractor's engine power and power range according to its weight

Podatki o stopnji emisij onesnaževal za nove, prvič registrirane traktorje v Sloveniji so kot stopnje emisij onesnaževal (stopnja I, II, IIIA, IIIB in IV) na voljo za nove registrirane traktorje od leta 2014. Nekaj zadnjih let so bile podane le vrednosti posameznih onesnaževal. Analizirali smo podatke za traktorje, ki imajo vpisano stopnjo emisij onesnaževal za prvih osem mesecev v letu 2014. Ugotovili smo, da je 0,2 % traktorjev s stopnjo I, 0,1 % traktorjev s stopnjo II, 79,1 % traktorjev s stopnjo IIIA, 20,5 % traktorjev s stopnjo IIIB in 0,1 % traktorjev s stopnjo IV. Iz tega je razvidno, da večina proizvajalcev in zastopnikov izkorišča možnost prehodnega obdobja, oziroma gre spreminjat tipsko homologacijo šele takrat, ko je to nujno potrebno.

ZAKLJUČEK

V Sloveniji je po Popisu kmetijstva iz leta 2010 101.756 traktorjev. Konec leta 2013 je bilo registriranih 100.965 traktorjev. Novi traktorji registrirani v letu 2013 imajo povprečno močjo 61,4 kW. Analiza novih registriranih traktorjev po različnih kategorijah moči kaže na to, da kupci novih traktorjev kupujejo bolj ustrezne traktorje glede na velikost svojih

kmetij. Število nakupov traktorjev v kategorijah traktorjev z močjo med 60 in 80 kW ter nad 80 kW se je stabiliziralo. Kmetje pa zaradi davčnih in drugih poslovnih zahtev ustanavljajo različne vrste podjetij, tako da je med lastniki novih traktorjev v letu 2013 bilo je 650 pravnih oseb in 875 fizičnih oseb. Med fizičnimi osebami med kupci prevladujejo moški stari med 50 in 60 leti. Glede homologacijskih zahtev za nove traktorje večina proizvajalcev in njihovih zastopnikov izkorišča možnost prehodnega obdobja glede predpisanih stopenj emisij onesnaževal za nove traktorje.

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SITUATION IN THE FIELD OF AGRICULTURAL TRACTORS IN SLOVENIA

ABSTRACT

In this paper, we analyzed the data of registered tractors in Slovenia. At the end of 2013, there were 100,965 registered tractors. In 2013, the average power of the new tractors in Slovenia was 61.4 kW. In recent years, there are no increasing trends of the number of tractors in the category with power between 60 and 80 kW and in the category above 80 kW. In 2013 there were tractors registered in categories T1, T2 and T5. Most - 19% of new tractors were registered in the registry area of Ljubljana. Among the owners of new tractors were 650 legal entities and 875 individuals. 91.5% of individuals are men and 8.5% are female tractor owners. Most owners (29.9%) were aged between 50 and

60 years. Most manufacturers are using the possibility of the transitional period about the prescribed levels of pollutant emissions for new tractors.

Key words: *number of tractors, power of tractors, new registered tractors, owners of tractors, Slovenia*



THEORETICAL LIMITS OF THE ANGULAR STABILITY RANGE OF THE TRACTOR MOVING OVER INCLINED TERRAIN

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ABSTRACT

In the paper is presented an analytical model, formulated for 3D simulation of the tractor's dynamic stability on inclined terrains. Assuming the constant velocity and curvilinear trajectory of constant radius, it accounts for the gravity force, but also include in analysis the inertial force appeared because of curvilinear motion of the tractor. An appropriate computer code has been developed on the base of formulated algorithm, and applied to estimate the stability ranges of three tractors: Fendt Farmer 312, Fendt 926 and John Deer 6400. Tractors were tested for operational velocities in the range between 0 and 50 km/h, and for turning radiuses of 15 m and 60 m. The model represents a suitable tool for preliminary estimations and comparisons of stability areals of the tractors operating at horizontal and especially at sloped terrains at different velocities.

Key words: *Dynamic stability, 3D analytical model, agricultural machines*

INTRODUCTION

Fast growth of mankind population demands adequate increase of food production. In order to meet this requirements, contemporary agriculture is under high pressure to use arable lands which characteristics, including configuration, are far away from those that previously had been recognized as optimal. Among many other negative consequences, this means that agricultural mechanization has to be used not only over the fairly horizontal, but also at the inclined terrains that impose specific operational conditions. In order to meet these additional requirements, various special tractors have been designed Mashadi 2009.

Within these enlarged areas of application, tractors (as multifunctional power machines) and tractor aggregates are often operated under working conditions that are beyond technical security limits. Among them, centrifugal inertial forces, which ordinarily arise

during curvilinear motion of the tractor, joined to the influence of inclined terrain, represent important source of rollover accident hazard.

Thus, tractor has become a source of injuries and even deaths (Murphy 1991, Myers 2000, Myers et al 2000, Shutske et al 2004, Franklin et al 2006, Dimitrovski et al 2009, Dolenšek et al 2010, Oljača et al 2010). According to Gligorević 2013, USA National Safety Council reported that about 36% of tragic accidents in agriculture in 2003 were related to tractors. Therefore, special attention has been paid in USA to safety during tractor operations (Anonymous 2004). Lesley (1998) claimed that accidents with tractors occupy 72% of the total number of accidents in agriculture in Australia. Among them, 61% of accidents were results of tractor rollovers. Gligorević 2013 reported that many accidents related to agricultural mechanization in Serbia, have been caused by tractors rollover.

Centrifugal inertial forces, which ordinarily arise during curvilinear motion of the tractor, joined to the influence of inclined terrain, represent an important source of rollover hazard. In addition, stable tractor movement, which is of crucial importance for preserving the optimal drawing properties and other working characteristics (Djević 1992).

These facts represented the main motive for some researchers to focus their attention to the problem of tractors stabile and safe operation. There are many possible approaches to analysis of the tractor stability and angular range of their applicability.

Having in mind the important influence of inertia tensor on the tractors dynamic stability, Vitas et al 1988 reported method for determination of inertia tensor of farm tractors. On the other side, Gligorić et al 1998 analyzed tractor stability at inclined terrain, separately in longitudinal and lateral vertical plane. This way, presented analysis was two dimensional. Djević et al 1990 have presented 3-D model, which enables estimation of tractor-machine aggregate static stability range. This model has been later applied in Djević et al 1995 for estimation of component distribution influence on stability properties of different configurations of tractor aggregate. Novaković et al 1999 used the same algorithm to analyze stability areal of forklift aggregated to tractor, while Petrović et al 2007 applied it to estimate critical angles that define static stability limits of a wheat harvester under different operational conditions.

Pranav and Pandey 2008 presented a mathematical model and software for simulation of ballast management for agricultural tractors. Serrano et al 2009 have analyzed the effect of static and liquid ballasts, as well as the tire inflation pressure on tractor performance. They reported that the use of liquid ballast in the tires did not improve work-rate, and caused a 5%–10% increase in fuel consumption per hectare. Ahmadi 2013 examined the effects of different geometries and mass specifications of a tractors operating across rough sloped grounds on their lateral stability, and formulated dynamic model based on the tractor stability index to analyze overturn and skid instabilities. In this study, a static instability angle of 45° was obtained for the examined tractor, similarly to Sillesi et al 2007.

A radical idea was proposed by Myers et al, 2006: “Rollovers are more frequently reported to have occurred on sloping terrains, often during a sharp turn at high speed, although data show that rollovers do occur on flat land after hitting obstacles or through inappropriate use and hitching of implements.” In addition, Myers, 2008 stated, “The general ground slope may be small but its roughness can cause local slopes to become steep, and these local slopes may cause tractor overturn.”

Radoja et al 2000 summarized principles of tractor's safe work over highly sloped terrains:

- maximum allowed longitudinal slope of the terrain is 15% for the tractor with load, 20% without load, and 35% for the tractors of special design;
- tractors must be equipped with slope control units;
- tractor aggregates should move uphill, at velocities up to 5 km/h (depending on the operational conditions), and only 2 km/h while working at slippery terrains;
- rollover protection structure (ROPS) or cabin is necessary, as well as the seat belt;
- design of the tractor should provide the lowest possible position of the gravity center, at largest possible distance from the rear wheels;
- under operational conditions related to wet, frozen, or moody terrain, tractor acceleration should be carefully controlled.

THEORETICAL RESULTS: TRACTOR STABILITY MODEL

This study is focused to formulation of analytical model for approximation of the tractor's dynamic stability range. It is founded on the principles of theoretical mechanics and 3D analytical geometry, as well as the following basic assumptions:

- tractor is an indeformable solid body, moving at constant velocity;
- terrain is ideally flat and, therefore, characterized by constant slope;
- tractor's trajectory is characterized by constant radius $r = \text{const.}$;
- Descartes coordinate system is defined with respect to Fig. 1.

Thus, the algorithm recognizes tractor (Fig. 1a) as an in deformable body, supported at four points (centers of wheel contact surface areas with plain sloped terrain), which defines trapezoid presented in Fig. 1b. Stability of the tractor can now be estimated following principles of theoretical mechanics. This means that action line of resulting force $\vec{R}$, acting to the model tractor, must intersect the inner area of supporting trapezoid (Fig. 2).

Resulting force vector $\vec{R}$ is a vector sum of tractor gravity force (or simply, weight)

$$\vec{G} = m \cdot \vec{g} \quad (1)$$

and centrifugal force vector $\vec{F}^c$, which intensity is given by expression

$$F^c = \frac{m \cdot v^2}{r} \quad (2)$$

where m is the tractor mass, $v = \text{const.}$ designates velocity and r is the curvature radius. Therefore, resulting force vector can be analytically expressed by formula:

$$\vec{R} = \vec{G} + \vec{F}^c = m \cdot g \cdot \vec{k}_0 \pm \frac{m \cdot v^2}{r} \cdot \vec{i} \quad (3)$$

where $\vec{k}_0$ and $\vec{i}$ are ort-vectors of Oz_0 and Ox coordinate axis, respectively.

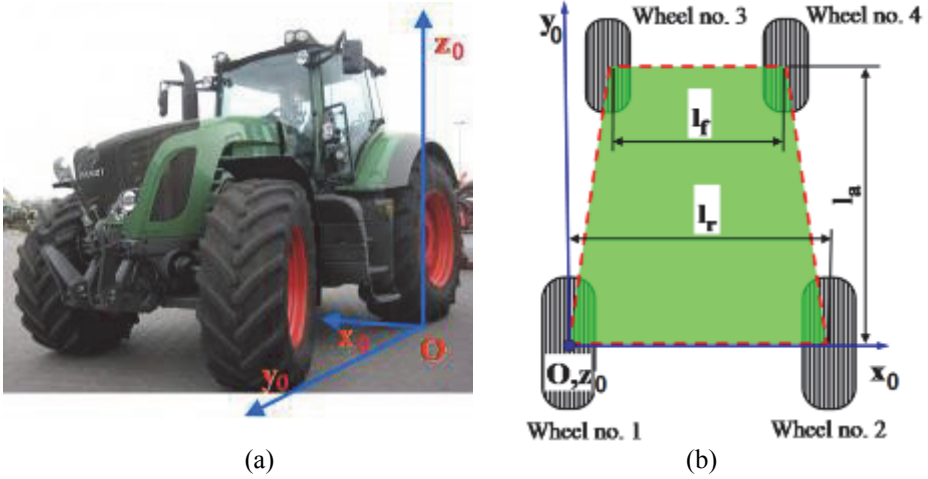


Fig. 1 Foundations of the tractor's dynamic stability model: (a) reference Descartes coordinate system and (b) definition sketch of the trapezoid supporting surface; Symbols: l_f – front wheels distance; l_r – rear wheels distance and l_a – inter-axial distance

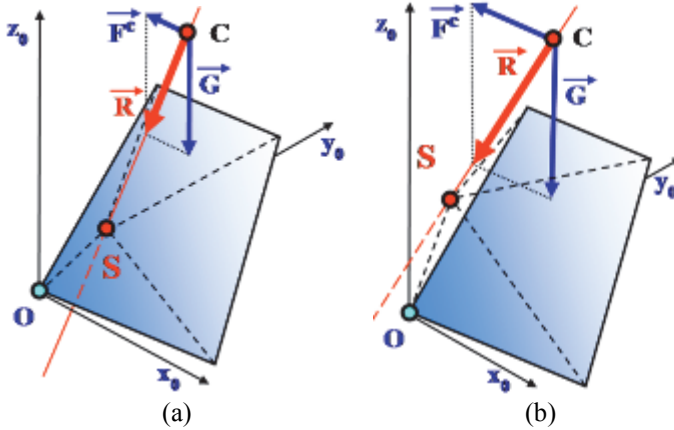


Fig. 2 A sketch defining the analytical interpretation of the stability criterium: (a) stable work and (b) instability. Symbols: W_1, W_2, W_3, W_4 – tractor wheels; S – intersection point between action line of resulting force and supporting trapezoid

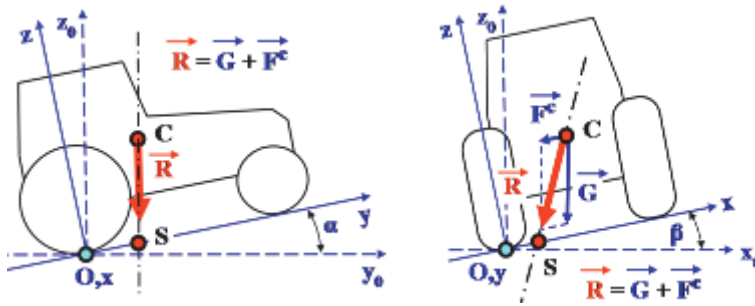


Fig. 3 Gravity and centrifugal force of the tractor at uniform curvilinear motion: (a) longitudinal slope and (b) transversal slope. Symbols: $\vec{R}$ - resulting force; $\vec{G}$ - weight and $\vec{F}^c$ - centrifugal force

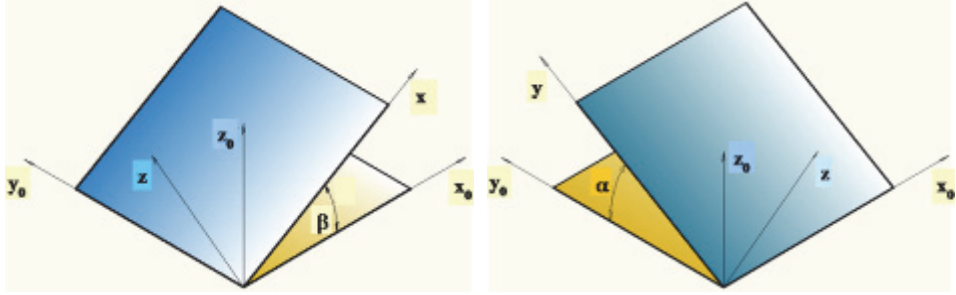


Fig. 4 A sketch defining longitudinal and transversal slope of model terrain

Action line of vector $\vec{R}$ intersects terrain at point S , Fig. 2. Stability criterion is:

$$A(\Delta W_1 W_2 S) + A(\Delta W_1 W_3 S) + A(\Delta W_3 W_4 S) + A(\Delta W_4 W_2 S) = A(W_1 W_2 W_3 W_4) \quad (4)$$

Transversal and longitudinal slopes (Fig. 4) are modelled following Djević et al 1990: by rotations, L_{y0} and L_{x0} , of the supporting points W_1, W_2, W_3, W_4 and mass center “C” around Oy_0 and Ox_0 axis of the fixed reference coordinate system $Ox_0y_0z_0$, respectively. Thus, if the position of point “ W_j ” ($j = 1, 2, 3, 4$) is defined in the fixed coordinate system by vector r_j , its location on the surface with transversal slope angle β is:

$$r_{Tj} = [L_{y0}] \cdot [r_j], \quad (j = 1, 2, 3, 4) \quad (5)$$

In analogue, longitudinal slope angle α is modeled by matrix multiplication:

$$r_{TLj} = [L_{x0}] \cdot [r_{Tj}] = [L_{x0}] \cdot [L_{y0}] \cdot [r_j], \quad (j = 1, 2, 3, 4) \quad (6)$$

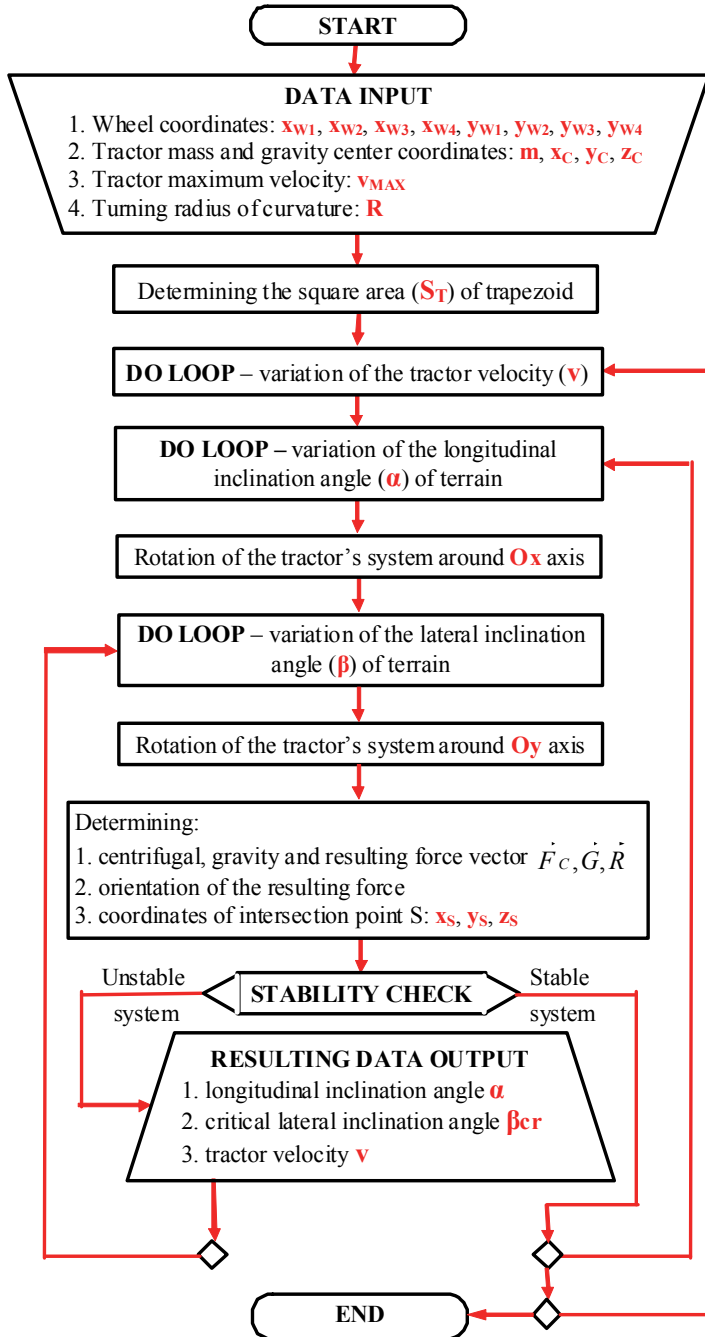


Fig. 5 Block diagram of the computer program

Matrices defining these two rotations are given by formulas:

$$Ly_0 = \begin{bmatrix} \cos \beta & 0 & \sin \beta \\ 0 & 1 & 0 \\ -\sin \beta & 0 & \cos \beta \end{bmatrix}, \quad Lx_0 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \alpha & -\sin \alpha \\ 0 & \sin \alpha & \cos \alpha \end{bmatrix} \quad (7)$$

The computer programm is coded and used to check the stability of three tractors: Fendt Farmer 312, Fendt 926 and John Deer 6400. Tractors were tested for velocities between 0 and 50 km/h (step 5km/h), and for turning radiuses of 15 m and 60 m. Longitudinal terrain slope is varied in the range between 0° and 45° (step 1°). Algorithm is presented in Fig. 5.

RESULTS OF SIMULATIONS AND DISCUSSION

Theoretical borders of tractor stability ranges are graphically presented in Figs. 6-8, depending on the moving velocity, transversal and lateral inclination angles of the terrain.

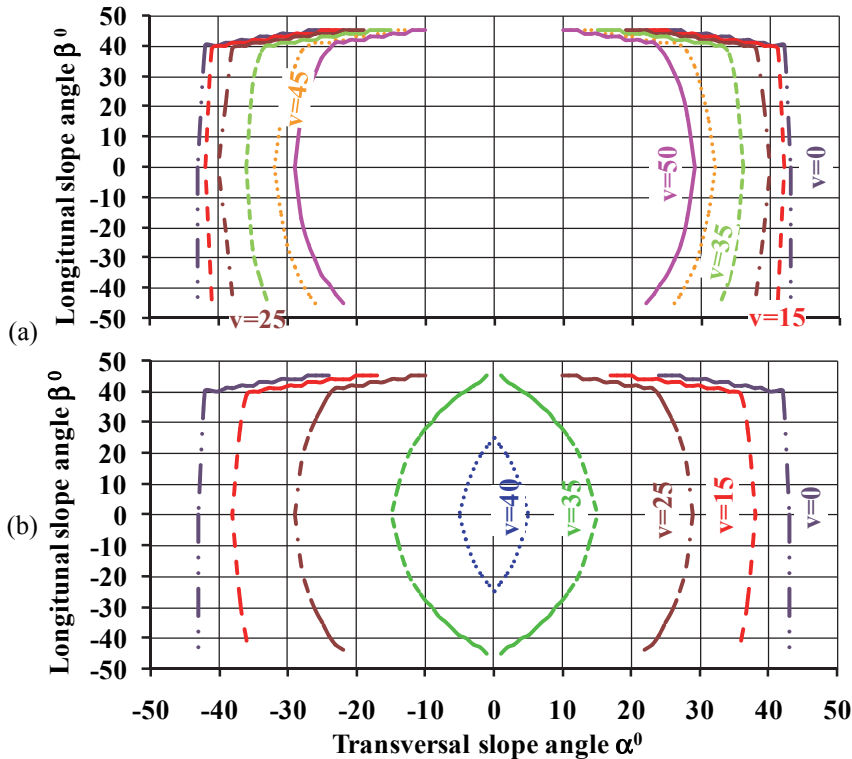


Fig. 6 Stability range of Fendt 926 for turning radius of: (a) 60m and (b) 15 m.

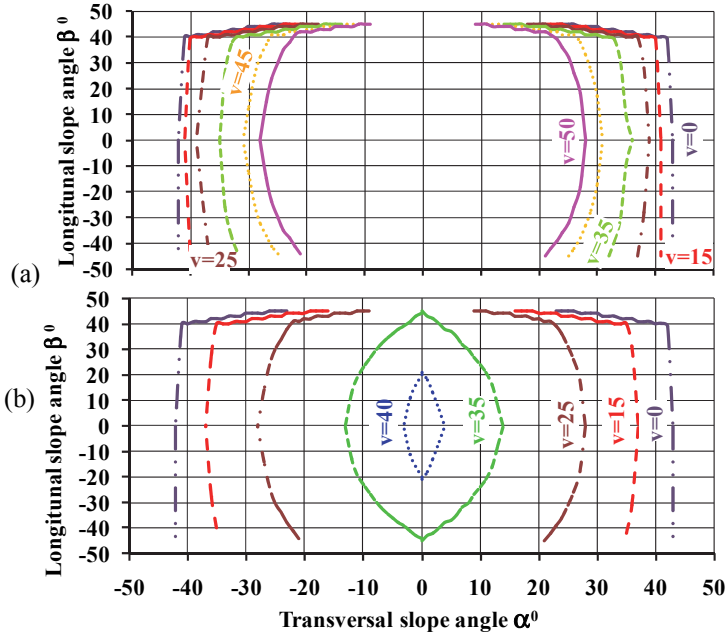


Fig. 7 Stability range of Fendt Farmer 312 for turning radius of: (a) 60m and (b) 15 m

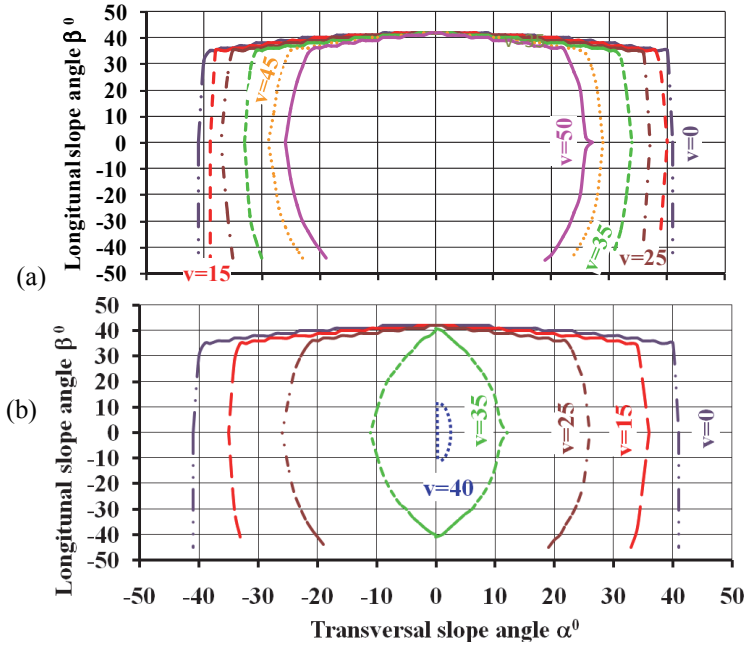


Fig. 8 Stability range of John Deere 6400 for turning radius of: (a) 60m and (b) 15m

Fig. 6 indicates that stability range of tractor Fendt 926 is larger in comparison to other two tested tractors. Its mass center lies at the longitudinal plane of symmetry, causing the symmetry of stability ranges. Evidently, decreasing of the radius of trajectory curvature causes rollover at smaller slope angles of terrain and tractor velocities.

In comparison to Fendt 926, tractor Fendt Format 312 becomes unstable at lower velocities and smaller slope angles. Its mass center lies slightly asymmetrical with respect to tractor symmetry plane, causing the slight asymmetry of stability range, Fig.7.

Tractor John Deere 6400 becomes unstable at smaller slopes angles with respect to the first two tested tractors. The graphics (Fig. 8) presenting stability ranges are asymmetrical, because its mass center is out from the plane of longitudinal symmetry.

As it is expected, the influence of the velocity is stronger on the transversal stability in comparison to longitudinal. According formulated simulation model and principles of theoretical mechanics, tractor stability is a function of mass center position, locations of centers of wheels contact points (centers of contact surfaces of each wheel with terrain), longitudinal and transversal slope angles of terrain and moving velocity of the tractor.

CONCLUSIONS

Paper presents an analytical model, formulated for 3D simulation of the tractor's dynamic stability, while moving at constant velocity over sloped terrain. Assuming the curvilinear trajectory of constant radius, it accounts for the gravity force, but also includes in analysis the inertial force appeared because of curvilinear motion of the tractor. An appropriate computer code has been developed on the base of formulated algorithm, and applied to estimate the stability ranges of three widely used tractors: Fendt Farmer 312, Fendt 926 and John Deere 6400. Tractors were tested for operational velocities in the range between 0 and 50 km/h, and for turning radiuses of 15 m and 60 m. The longitudinal slope angles of terrain are varied in the range between 0 and 45°, with step 1°. Simultaneously, transversal inclination angle is varied from 0° and up to the value causing tractor rollover, with step 1°.

Achieved results indicate decreasing the range of allowed terrain slope angles with decreasing radius of curvature of tractor trajectory and with increasing the tractor velocity. In the analysed test conditions, allowed values of longitudinal and transversal angles decrease from about $\pm 40^\circ$ for static conditions to less than about $\pm 20^\circ$. for the highest tested velocities (50 km/h).

Formulated mechanical model of tractor stability represents a suitable tool for estimations and comparisons of stability areals of the tractors having curvilinear trajectories, during operation at horizontal and especially at sloped terrains at different velocities having constant intensities. This model can be also applied for many other types of vehicles.

Results presented in Figs. 6-8 are theoretical approximation of the real operational conditions. In order to reach practical applicability of calculated critical values of slope angles at specified tractor velocities, results of simulation should be corrected by introduc-

ing a factor of safety – according to Pospelov 1966, all calculated values of slope angles should be reduced by 40%.

ACKNOWLEDGEMENT

The study is supported by Ministry of Education and Science of Republic of Serbia, under project TR-31051, “Improvement of biotechnological procedures as a function of rational utilization of energy, agricultural products productivity and quality increase”.

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CHECKING THE MECHANICAL RESISTANCE OF AN OPERATOR PROTECTION STRUCTURES

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ABSTRACT

This paper presents issues related to static testing of protective agricultural equipment structures and includes a description of the tested structure, *the testing method, the testing conditions and the obtained testing results and those analyses*. The protection structures along with the safety belt are designed to reduce the risk of injuring the operator in case of *overthrow / rollover* or accidental collisions of the agricultural equipment. *The attempts for checking the mechanical strength of protective structures from agricultural operator machinery, are concerned with checking the protection degree that these structures assures the driver in case of overthrow / rollover or accidental collisions when operating or machinery is in transport mode.*

Key words: static testing, protective structure, tractor

INTRODUCTION

Protection structures (cabins) represent an essential element of the agricultural and forestry tractors because on their resistance depends the safety and health of the operators who manoeuvre them. Major risks can appear in the public roads transportation (rollovers, collision, etc.), during the execution of different exploitation operations (accidental bumps, rollovers, etc.) or when working in rough areas (rollover, falls or accidental bumps, etc.). Proper testing of these protection structures represents an essential element in order to eliminate the risk of injury to the operator and to increase safety in case of overthrow / rollover.

Protection structures for tractors must be designed and constructed so that they are sturdy and resistant, and in case of unforeseen events / accidents during exploitation (execution of different operations) or transportation of the tractor on agricultural / forestry,

on slopes or rough roads, to ensure an adequate protection for the operator: the protective structure shall not break or deform as much as to enter in the operator's safety space – DLV (as defined in [13] and [14]).

In order to achieve optimized protection structures that ensure protection and safety for the operators, before their actual testing, in recent years, the final element analysis (FEM) is used increasingly [1, 4, 7, 8], but also the research on stability and designing of protective structure of tractors [2].

The verification of the safety that resistance structures provide for operators can be also achieved by dynamic tests [3, 11] when there are no specialized installations for the static testing of structures (ROPS), which is a complex test that needs extremely complex testing installations [5, 6, 11, 12].

In order to analyze the risk to which the operators are subjected to as a result of an accidental rollover of the tractor, numerous researches were conducted: by simulation, procedures and testing methods analysis [9,10], using new monitoring methods [5], by conducting tests in simulated and accelerated regimen or not [6], by using the static or dynamic [11] testing method.

MATERIALS AND METHODS

The protection structure – the cabin, has the role to provide safety and comfort conditions for the driver that manoeuvres a tractor destined for agricultural / forestry exploitation. It consists of a resistance frame made of OL 42 profiles with different sections assembled by welding and a coating of OL 37 steel sheets. The resistance frame of the cabin is composed of two side walls made from 60x40x4 rectangular pipes, assembled by welding, in the middle having an extra pole for consolidation made of the same material. In the frontal part, the cabin is strengthened using pillars and beams made of 50x50x5 square pipe. The roof is made of two transversal and three longitudinal reinforcements made of 40x25x3 rectangular pipe. The cabin is equipped with two side doors, made of 40x25x3 rectangular pipe, the lower part being coated with 3 mm steel sheet, and the top is fitted with a window. In the frontal part, the cabin is equipped with an unbreakable polycarbonate windshield.

Specification for the tractor for which the test were conducted

- Mass of the tractor without load, with its protection device, without driver: 8355 kg;
- mass of the cabin: 645.168 kg;
- the cabin fitting on the tractor is made using elastic pads, on specific front/rear supports;
- the temperature at which the tests were conducted was approximately 25° C;
- the bolts used for testing were 8.8 mm ones, and the nuts 8.9.

The cabin is equipped with two side doors for left/right access, fixed front and side windows and an opening rear window.

Researches were conducted at INMA Bucharest – Testing Department on the installation for testing in simulated and accelerated regime type Hydropulse (fig. 1).



Fig. 1 Installation for testing in simulated and accelerated regime type Hydropulse, Overview

RESULTS

In order to conduct the experiments, the protection structure (the cabin) was fixed on the testing platform through a system of universal and specific devices.

Taking into consideration the dimensions of the cabin and the difficulty of the test, the clearance area inside was materialized by making a tridimensional wire structure and positioning it in the cabin depending on the seat reference point.

The point of load application in the case of a longitudinal test, a drive from front to back, was at a distance of $1/2$ of the width of the top part of the protection structure, measured from the left exterior corner towards the interior, rear view (fig. 2). The length of the beam with which the uniform distribution of load was achieved was 500 mm.

For the compression test, a beam was used, with the width of 250 mm and placed above the vertical projection of the DLV (fig. 3), where DLV is the zone of clearance is defined in relation to a vertical reference plane generally longitudinal to the tractor and passing through a seat reference point and the centre of the steering wheel. The reference plane shall be assumed to move horizontally with the seat and steering wheel during application of the load but to remain perpendicular to the floor of the tractor or of the protection structure if this is resiliently mounted.



Fig. 2 Fitting made on the “HIDROPULS” installation for the testing of the tractor cabin in the case of applying a longitudinal load from the front



Fig. 3 Fitting made on the “HIDROPULS” installation for the testing of the articulated skidder cabin in the case of crushing

The point of load application in the case of lateral testing was on the top edge of the protection structure in the path of the prominence that could reach the soil first in case of rollover on the right side of the cabin, on the right pole (fig. 4)



Fig. 4 Fitting made on the “HIDROPULS” installation for the testing of the articulated skidder cabin in the case of applying a lateral load

For the test were used: a hydraulic cylinder of 250 kN (for the longitudinal and lateral drive tests) and two 100 kN cylinders (for the downforce tests).

The testing parameters and their values are presented in table 1 and were established complying with [14].

Table 1

Test type		Testing parameters		
		Name	U.M.	Minimum values calculated according to [14]
Horizontally	Force applied longitudinally from the front	Force	kN	38.69
	Force applied laterally	Force	kN	79.8
	Lateral load	Energy	J	9984.9
Vertically	Down force	Force	kN	167.1

The testing parameters and their values are presented in relation (1) and were established in accordance with the regulations in force:

$$U = \frac{\Delta_1 * F_1}{2} + (\Delta_2 - \Delta_1) \frac{F_1 + F_2}{2} + \dots (\Delta_N - \Delta_{N-1}) \frac{F_{N-1} + F_N}{2} \quad (1)$$

where: F - force; Δ - displacement; U - energy;

- Energy absorbed when applying the lateral load: 11449.7 J;

- Force applied laterally: 143.1 kN[
- Force applied vertical: 169.8 kN[
- Force applied longitudinally from the front: 45.1 kN.

The force/displacement, force/time, force/energy for each of the tests performed (fig. 5, 6, 7 and 8) has the following forms:

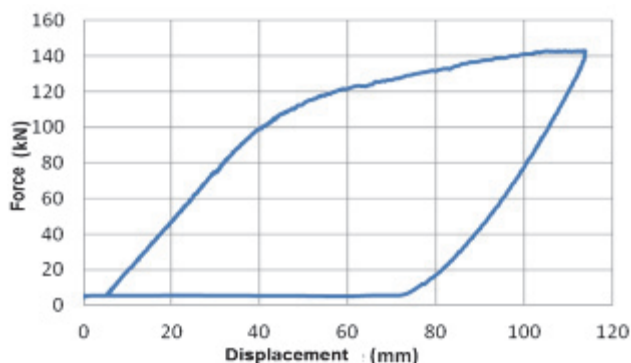


Fig. 5 The force-displacement diagram for lateral stress to the cabin

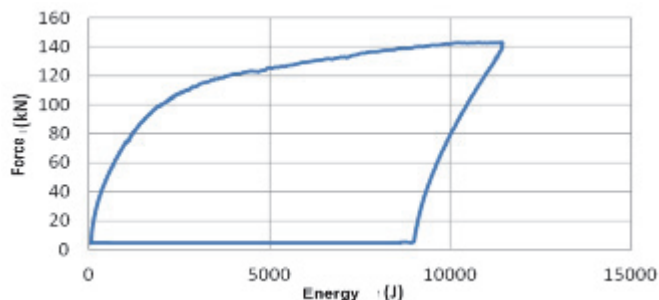


Fig. 6 The force-energy diagram for lateral stress to the cabin

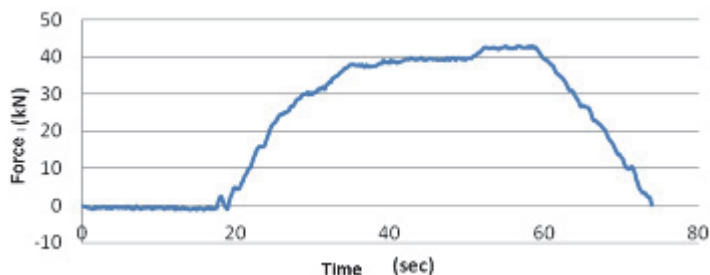


Fig. 7 The force-time diagram for longitudinal stress to the cabin

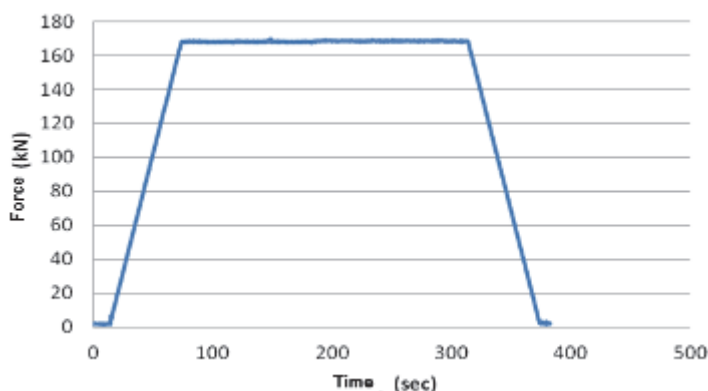


Fig. 8 The force-time diagram for vertical crushing

CONCLUSIONS

The cabin on which the research was made is destined to protect the tractor driver and the persons accompanying him, from the dangers which may arise in case of tractor rollover, or to limit their effect.

The values of the stresses to which the product was subjected were determined based on the documentation and data extracted from different standards and current regulations.

The tests were conducted on the installation for testing type Hydropulse and aimed at verifying the capacity to intake energy and forces applied to the cabin for the values calculated according to a reference tractor mass of 8355 kg.

After performing the tests, the cabin showed visible fissures at the welded joints of the front poles, which did not allow its penetration into the DLV (deflection-limiting volume).

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ACCELERATED TEST OF MAS 65 DEEP SOIL LOOSENING MACHINE FRAME

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SUMMARY

The resistance frame of the MAS 65 deep soil loosening machine, also called frame, represents an essential component for its optimum functioning. The machine's frame is subjected to composed mechanical strains during exploitation which could destroy its integrity. The verification of the frame's resistance could be made directly in the field, through the exploitation of several hundred hectares during a working season or in laboratory conditions. Within the paper it is presented the testing method in laboratory, through simulating the field strains, based on the real stress spectrum at which the structure is subjected. After applying a rain flow type cycle counting algorithm and synthesizing a test program based on it, the frame is tested in accelerated regime within laboratory, being mounted on a testing stand fitted with hydraulic actuator. The test purpose is to experimentally determine the frame's exploitation resistance in a reasonable amount of time and with minimum costs. The presented testing method could be generalized for most of agricultural equipment, representing a powerful tool in stages of designing and validation of a new product.

Key words: accelerated test, rain flow, resistance frame, real stress spectrum

INTRODUCTION

Testing of technical equipment before emerging on the market represents a base condition for assessing their reliability, safety in exploitation as also the obtained performances. This testing can be performed in exploitation conditions but it's costly and uses large amounts of time, usually reaching the expected life of the equipment. An alternative is represented by accelerated testing. Accelerated testing can be obtained through many methods [1] by which we remind the compression of the testing period together with raising the strain level or raising the frequency and/or amplitude of strains, in

function of the requirements. Thus we can obtain shorter testing periods, direct proportional with the acceleration factor [4].

Agricultural machinery manufacturing industry is characterized by the same testing patterns in what concerns their performances as the other technical equipment. The principles used remain the same ones as in the aeronautical [5] or car manufacturing industries. Thus is very important to identify the stress spectrum at which the car is subjected. Based on this, on the used materiel properties, and after applying a cycle counting algorithm and correlated with a damage addition rule (e.g. Palmer-Miner), one could determine the expected life of the structure. Also it could be realized an accelerated testing program [7,8] at which the structure to be subjected in laboratory conditions for assuring a minimum life expectancy, for example a minimum number of seasons in which the structure could be exploited.

The main strains of agricultural machines are of mechanical type and they have a direct effect on their resistance structures, also called frames. In this paper we refer to the deep soil loosening machine MAS 65, whose frame is highly stressed in exploitation. Because of this reason there could appear permanent deformations or fissures which could affect its structural integrity and the working capacity. For avoiding such situations, the frame has to be tested in the field and/or in laboratory conditions. In order to obtain the results which evaluate the frame from the resistance in exploitation point of view, we chose to identify the stress spectrum in the field, based on which to synthesize an accelerated testing program in laboratory conditions. After that the frame was subjected to this testing program, simulating the usage during one exploitation season.

METHOD

In order to obtain the most stressed points in exploitation of the MAS 65 resistance frame, first we performed a finite element analysis, in static regime on the machine's structural model, applying methods presented in [3]. The structural model was realized using one-dimensional elements, with the same materiel characteristics, in COSMOS WORKS software. Modeling was made in the hypothesis that loads are performed in the elastic domain, mechanical tension being computed after Hook's law [2]:

$$\sigma = E * \varepsilon \quad (1)$$

In figure 1 we present the deep soil loosening machine MAS 65 mounted on a 58.9 kW (80 HP) tractor, and in figure 2 we show the field of equivalent stress (Von Mises) into the structure, obtained after finite element analysis. The used loads were pure theoretical because the purpose of modeling was only to identify the frame's critical points. There were identified 14 points in which we have applied strain gages for measuring strain during exploitation.

After mounting of strain gages we have performed field tests in order to determine the real stress spectrum of the frame in exploitation. Tests were done at maximum working depth of 65 cm, in two types of filed: worked and unworked. We have identified as main excitation source for the frame the working organ of the MAS 65, through which the

reactions from the soil are transmitted to the frame. Thus, a strain measuring point was chosen on the working organ. The evolution in time of the strain for that point was used for synthesizing the accelerated testing program in laboratory conditions. In figure 3 we present the tensions obtained in the field and the resulted stress spectrum after concatenation of the obtained signals in the two types of terrain.



Fig. 1 Deep soil loosening machine MAS 65 mounted on the 80 HP tractor

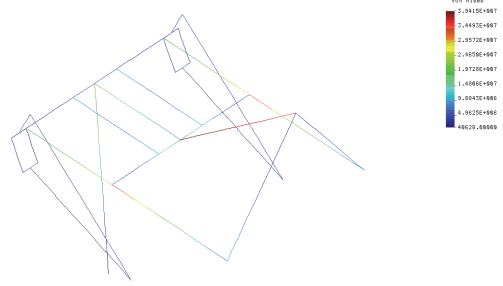


Fig. 2 The field of equivalent stress (Von Mises) into the structure, in Pa

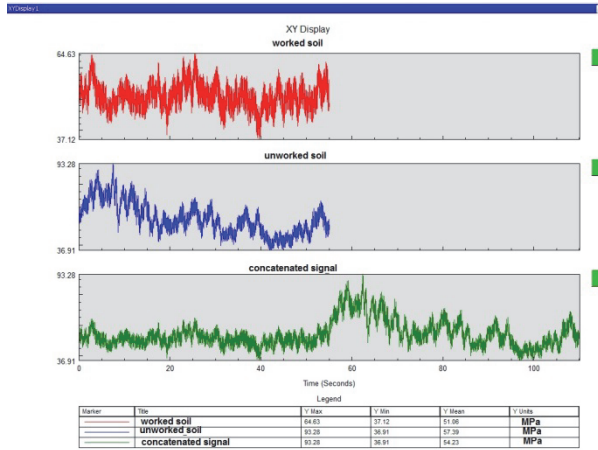


Fig. 3 Real stress spectrum obtained after in field experiments, for the working element of the MAS 65 machine

The so obtained spectrum was subjected to the following method for synthesizing the accelerated test program. First there were calculated the values of the mean stress σ_m and the range stress σ_a , applying the following equations to the string of concatenated data:

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} \quad (2)$$

After we have eliminated the intermediary cycles with ranges smaller than 10% of the maximum recorded ranges and we applied a rain flow cycle counting algorithm [9], in hypothesis of using a mean stress common for all the stress cycles and of dividing the cycles in 10 bins. For each bin we calculated the range stress with equation 2. The general signal frequency was obtained using equation.

$$\vartheta = \frac{N_{tot}}{t_{tot}} \quad (3)$$

in which N_{tot} represents the total number of cycles counted over the total period of the concatenated signal t_{tot} . After that, by multiplying the number of cycles obtained for each bin with the general frequency we have obtained the actual time width t_i of each bin.

$$t_i = \frac{N_i}{\vartheta}, \text{ with } i = 1 \div 10 \quad (4)$$

So that

$$t_{tot} = \sum_{i=1}^{10} t_i \quad (5)$$

For calculating the testing frequency for each bin we proposed the following algorithm:

$$\vartheta_i = \frac{\sigma_a N_i}{\sigma_{ai} t_i}, \text{ with } i = 1 \div 10 \quad (6)$$

Equation 6 permits increasing of testing frequency inverse proportional with the range stress. This is necessary in order to accelerate the test together with tacking into account the frequency response of the testing stand.

We synthesized after that a loading sinusoidal signal with the amplitude and frequency calculated before and the common mean stress obtained for the concatenated signal, applied for the each bin corresponding number of cycles. The accelerated time width for every bin is obtained by dividing the corresponding number of cycles to the calculated accelerated testing frequencies. The so obtained signals were linked together in a train of signals, according to the following formula:

$$\sigma(t) = \sum_{j=1}^{10} [\sigma_{aj} \sin(2\pi\vartheta_j t) + \sigma_m] * k, \text{ with } k = \begin{cases} 1 & \text{for } t \text{ in current bin} \\ 0 & \text{for } t \text{ outside the bin} \end{cases} \quad (7)$$

Equation 7 represents a synthetic variation of the Gassner's eight blocks method [5], in which intervenes also the information referring to frequency and the time width of loads.

The effective time width for each bin is calculated according to:

$$T_i = \vartheta_i N_i, \text{ with } i = 1 \div 10 \quad (8)$$

The so obtained signal was applied as reference for a hydraulic actuator, used as a excitation source for the soil working organ of the MAS 65 machine. This signal was

applied repeatedly until achieving the number of cycles estimated to stress the structure during an exploitation season.

In figures 4 and 5 we present the testing stand prepared for performing the accelerated test within laboratory. We simulated the mounting in three points to the tractor using a specific device and also the propping of the working depth establishing wheels, by putting them on top of two beams. The frame was loaded through its soil working organ on which we have applied the force by using a hydraulic actuator. The soil working organ wasn't observed during the accelerated tests.



Fig. 4 Accelerated testing stand for the resistance frame of MAS 65 machine



Fig. 5 Detail presenting the coupling between the hydraulic actuator and the soil working element

RESULTS AND DISCUSSION

After field experiments we obtained the diagrams presented in figure 3. The total observed time obtained by concatenation was $t_{\text{tot}}=110$ seconds. Applying the rainflow counting algorithm to the obtained signal, with a gate factor of 10%, it resulted a total number of 498 stress cycles. In figure 5 we presented the histogram obtained after rainflow

counting, using Glyphworks software. We can observe that the data distribution is almost normal, which corresponds to the random character of the recorded data.

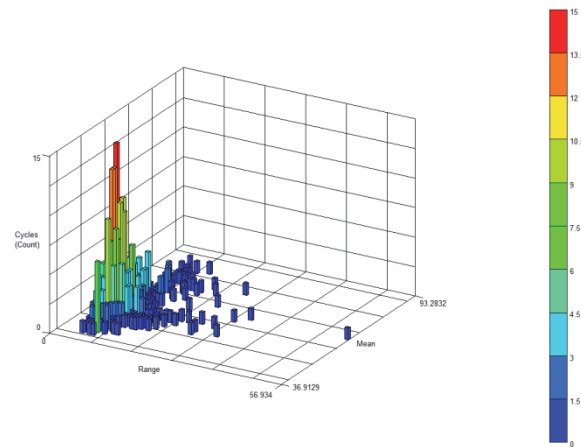


Fig. 6. Rain flow cycle counting algorithm results

The obtained cycles were divided by their range stress in 10 bin of equal width, with a common mean stress. In figure 7 there are shown the resulted bins.

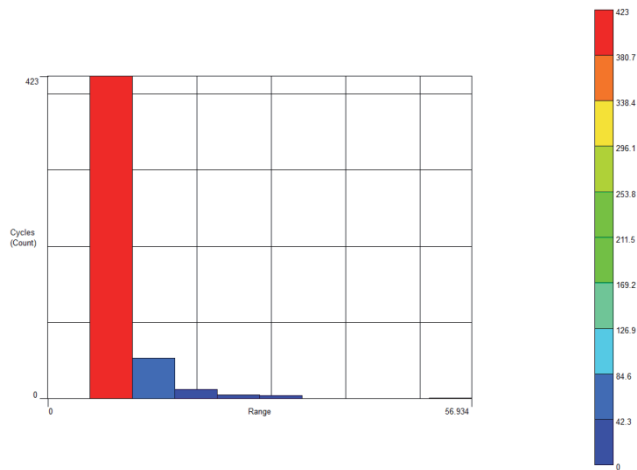


Fig. 7. Number of cycles per testing bins

The range stress σ_a calculated for the original concatenated data was of 28.185 MPa and the mean stress value σ_m was of 65.095 MPa. The calculated general frequency ν has the value of 4.527 Hz.

In table 1 we present the number of cycles N_i , the range stress σ_{ai} for each bin, the value of calculated testing frequency v_i , the width t_i of the resulted testing bins and the obtained width T_i correlated with the testing frequencies. The total accelerated testing obtained time has achieved the value of $T=38.05$ seconds.

Table 1 Results of the proposed testing algorithm

No of bin	No of cycles	σ_{ai} (MPa)	v_i (Hz)	t_i (sec)	T_i (sec)
1	0	2.8467	0	0	0
2	423	8.5401	14.94	93.43	28.31
3	53	14.2335	8.96	11.71	5.91
4	12	19.9269	6.40	2.65	1.87
5	5	25.6203	4.98	1.10	1.00
6	4	31.3137	4.07	0.88	0.98
7	0	37.0071	0	0	0
8	0	42.7005	0	0	0
9	0	48.3939	0	0	0
10	1	54.0873	2.36	0.22	0.42

We observe that by restricting the number of bins to 10 and correlated with the rainflow histogram results we have also bins with 0 cycles, so that the synthesized testing signal will be composed only of 6 components variable with time. In table 2 we show the time distribution of the signals composing the accelerated testing signal.

Table 2 Time distribution of the signals composing the accelerated testing signal

T (sec)	0÷28.31	28.32÷34.22	34.23÷36.09	36.1÷37.09	37.1÷38.07	38.08÷38.5
σ_a (MPa)	8.54	14.23	19.92	25.62	31.31	54.09

In figure 6 we present the synthesized testing signal after applying equation 7, using as input data the information presented in tables 1 and 2. In the diagram we can observe the 6 blocks obtained, modulated in frequency and amplitude.

Taking into account that we estimated a surface of 150 ha worked/season, with a medium working speed of 2 km/h and a medium working width of 1.5 m, the total number of stress cycles estimated per season was of 8964000. This fact implied the repetition of the accelerated testing program by 18000 times. The total amount of accelerated testing time was of 192.5 hours compared with the 500 hours of conventional testing. After completion of the tests we didn't find any fissures, ruptures or deformations in the frame of MAS 65 machine. The tests acceleration method used was that of weighted raising the test frequencies, according to equation 6. Performing the ratio between the initial total time of the concatenated signal and the total time of the synthesized signal, we got an acceleration

factor $AF=2.857$, which is very closed to the value of 3 obtained by other researchers for agricultural machinery and tractors [6]. In this way a working season could be simulated in 8 days of testing, the costs for this activity being much smaller than that of conventional testing. Also the time in which we get the results allows for assessment of machine's performances much quicker than in the conventional manner.

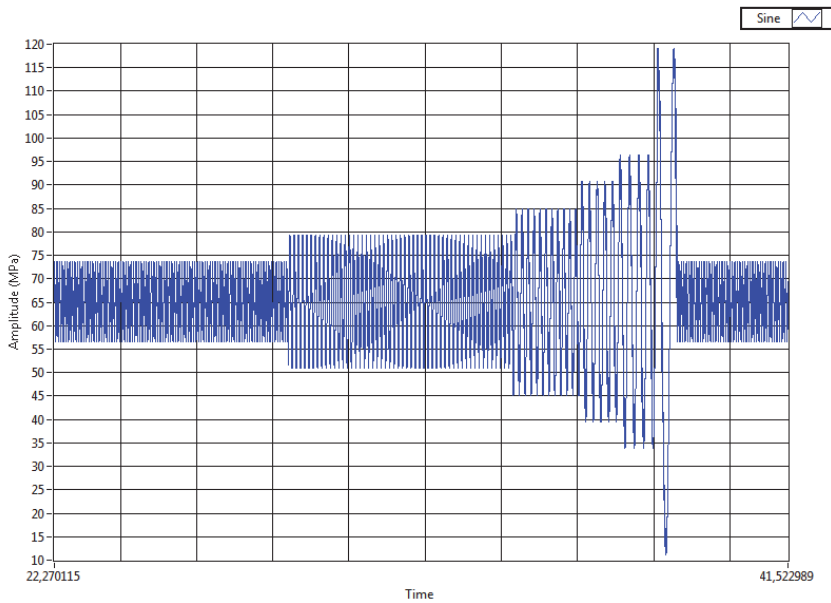


Fig. 7 Synthesized test program

CONCLUSIONS

As we can observe the rain flow counting algorithm does not contain any information referring to frequency of stress cycles. In the paper we proposed a calculus algorithm for the testing frequencies which takes into account the stress range, so that the testing frequency to be inverse proportional with the stress range. This permits a correct frequency response of the testing stand and also a good acceleration factor.

Agricultural machines for which we estimate a high degree of mechanical stress during exploitation, the determination of life expectancy and of reliability indicators in normal conditions presumes a large amount of testing time. Because of that one can choose accelerated testing methods. Those are tests performed at higher or quicker stress levels, compared with the normal stress level, in order to intensify the failure mechanisms of the equipment, and as an economical result the shortening of the testing period and the reducing of testing costs, in the conditions of keeping the same failure mechanisms. Within the accelerated tests we accept the hypothesis that the life expectancy of the product decreases proportional with the intensifying of the stress.

For realization of simulated and accelerated tests of a resistance frame, we propose the following stages: structural modeling, field experiments, accelerated test synthesis and laboratory tests. Whether the stress spectrum of the frame is known, one could renounce to the field experiments.

Tests in laboratory conditions will not describe totally the real situation from the field, because there are constraints regarding the geometry of the testing stand, limitations of the testing devices as also the missing of some field factors (for example speeds, accelerations, moving elements). Still this type of testing remains a valuable tool for engineers because of the possibilities to obtain in a very short amount of time information regarding the structural integrity of the equipment, its reliability, failure mechanisms, etc. Also the acceleration method and the value of the acceleration factor have to respect the engineers good practice guides.

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THE VERIFICATION OF STRESS BY FEM ANALYSIS/ MECHANICAL TESTING OF A TRACTION BAR

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ABSTRACT

The traction bar as well as other traction devices should be checked in terms of resistance which ensures while driving to the tractor-trailer aggregate. This may be verified by finite element analysis (ANSYS, COSMOS, KATIA, etc.) or by testing under simulated and accelerated special equipment.

This paper presents the results obtained by finite element analysis of the traction bar from a 200 HP tractor (after discretization model), determining the requested most powerful items and high-risk areas where fractures can occur, or after stress examination on the testing installation under simulated and accelerated regime to determine if in the following requests appear deformations or ruptures within.

Key words: tractor traction bar, FEM analysis of stress, mechanical testing

INTRODUCTION

The importance of machines, equipment or components testing results from the fact that different types of tests, as an integral part of the research, development, design, manufacture, exploitation and repairing process of the products, contributes significantly to their continuous improvement, in all phases. Mechanical tests are aimed:

- check if the main constructive parameters, technical and economic indices, quality of the execution, performance, safety of operation and wear resistance of the components, subassemblies or products correspond to the technical documentation of the manufacturing firms;

- to carry out a permanent control of the manufacture (reparation) quality, of verification and improvement of prototypes or of the new technological processes and materials etc., at the manufacturing and repair firms;
- in exploitation, to determine which is the type of component, subassembly or product most appropriate to certain working conditions as well as to establish the best working regimes;
- to obtain comparative technical data for new works of design or for manufacturing technological processes;
- to provide data for establishing the length of service of the component, subassembly or product.

After purpose, mechanical tests are classified in: durability tests and tests for the determination of various parameters. The durability tests are:

- *long-term tests*: are made to establish the length of service in actual operating conditions, characterized by normal testing regimes, corresponding those in actual exploitation;
- *simulated and accelerated tests*: is characterized by overloading the machines, equipments or components at forced regimes, reduced periods operating under laboratory conditions or on special tracks that provide such regimes.

Considering that the tests of the mechanical structures in simulated and accelerated regime, although they are relatively shorter duration than those achieved in operating conditions (about 10 times), are generally destructive - the structure deforms and can't be used, even if it is not cracked / broken.

Finite element analysis (FEM) [2, 3, 10] of the structures emerged as a necessity [1] to simplify and reduce the cost of testing in operation or in simulated and accelerated regime, this can approximate with an acceptable accuracy the areas with maximum requests (critical) [13], the maximum stresses and even the lifetime of a structure.

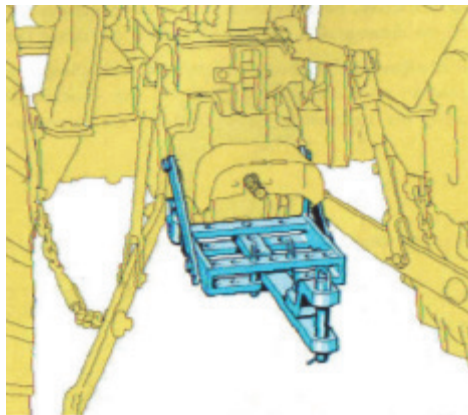


Fig. 1 The traction devices of bar type

For this purpose numerous researches have been achieved on the use of FEM analysis for: the study of interaction between the driving wheel and rolling track for agricultural land vehicles [4], the analysis of stress and strains distribution in an agricultural vehicle wheel, the analysis of the stress and strains distribution in various components of the tractor [6], the optimization of the wheel tires exploitation for agricultural vehicles, structural statistic analysis of lateral tensional bars of the suspension mechanism from the tractor [7], the behaviour at fatigue of various mechanical devices [9, 11, 12] of traction from the tractor, etc. If we refer only to traction devices of bar type (fig. 1) from the tractor, their testing is very important regardless of whether is achieved by simulation with FEM or testing in simulated and accelerated regime as it represents a critical safety element when the tractor is working in aggregate with a trailer.

MATERIAL AND METHODS

In order to achieve the numerical simulation for the study of the traction bar requests were made the following assumptions:

- *Charging* with a force inclined with 24.9 degrees to the horizontal, applied after a pulsating cycle with the asymmetry degree $R = 0.06$; $F_{\max} = 84.9$ kN; $F_{\min} = 5$ kN;
- *Propping* identical to that realized on INMA stand
- *The geometric model* was achieved based on the documentation provided by INMA Bucharest. The traction bar assembly was conducted based on all the execution drawings, using ANSYS software, respectively COSMOS.

The materials used in manufacture of the traction devices are:

- Steels of general use for constructions, STAS 500/2
- Quality carbon steel for heat treatment, STAS 880;
- Spheroidal graphite cast irons, SREN 1563;
- Steel for seamless tubes, STAS 8183.

The traction bar of the tractor is mounted on the rear chassis of the tractor and is aimed at the establishment of the link between the tractor vehicle and hauled vehicles. It is a strongly requested subassembly and represents one of the components that contribute significantly to the safety in exploitation. This is of type pendular rod and is positioned in the median longitudinal plane of the tractor.

For the analysis with finite element was used COSMOS WORKS 2007 software package and ANSYS simulation program. There was used three-dimensional finite element type tetrahedral with four nodes per element.

- Total number of elements = 280 493.
- Total number of nodes = 429 459.
- The total number of equations after imposing the conditions on the contour: 1287369.

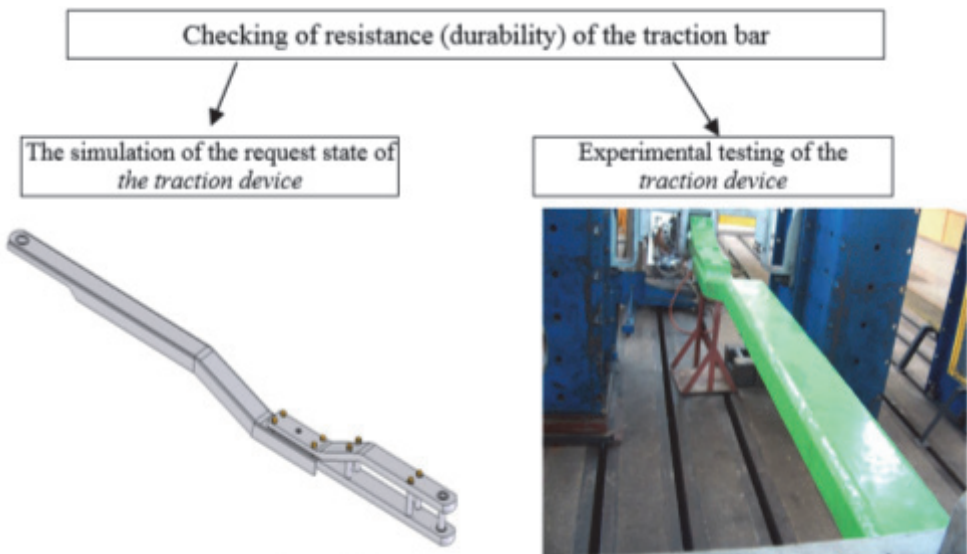


Fig. 2 Geometrical model

Fig. 3 Testing stand

The calculation model used with the presentation of meshing and conditions on contour is presented in Figures 4, 5 and 6.

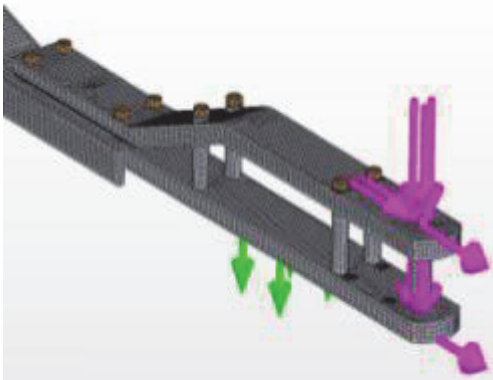


Fig. 4 Calculation model (detail end of traction)

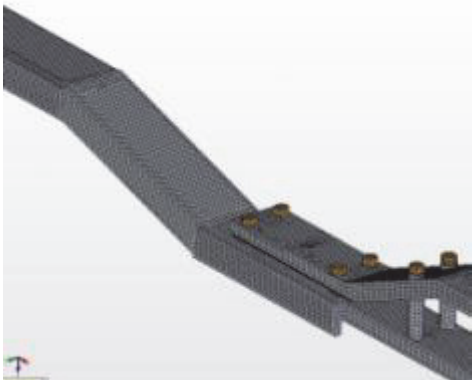


Fig. 5 Calculation model (detail central area)

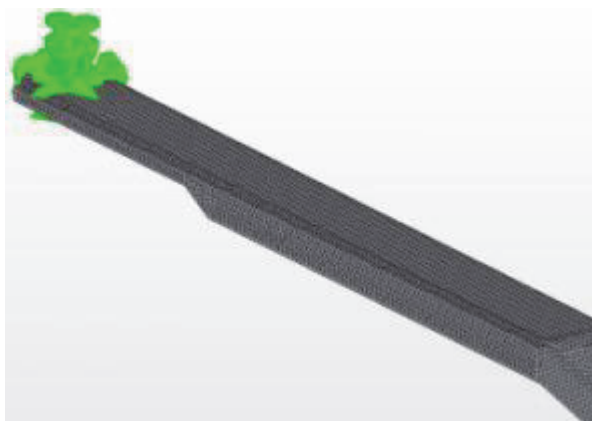


Fig. 6 Calculation model (detail area of fastening end)

The calculation model elaborated was conceived for both the static analysis of the stress and deformation states from the traction bar assembly and at the variable request of its.

Conditions on the contour and the charging applied to the geometrical model consist of a fixed bearing pad (Fig. 7), a bearing pad which allows the displacement of the traction device on the axial direction (Fig. 7b) and a traction force applied under an angle of 24, 5 degrees to the horizontal (Fig. 7c).

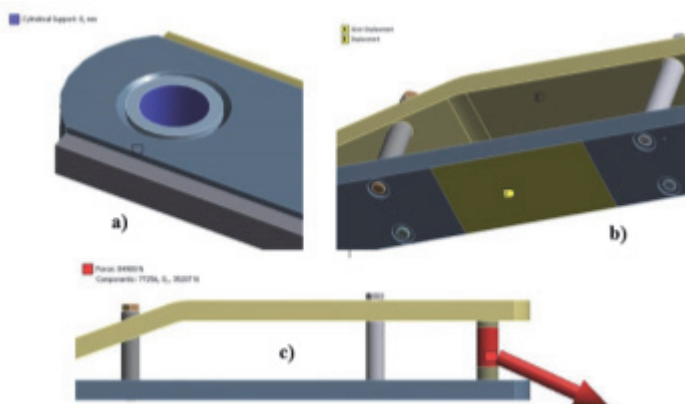


Fig. 7 The conditions on the contour

RESULTS AND DISCUSSIONS

Checking the resistance of the traction bar by simulating the state of request

The distribution of the state of stress and strain for the case of static requesting at the maximum force level of 84.5 kN (load applied under the conditions of charging shown), is presented in Figure 8, 9, 10 and 11.

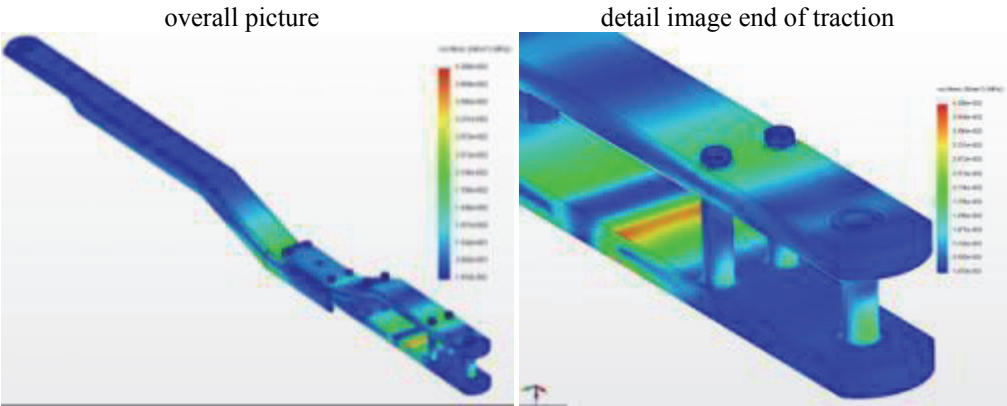


Fig. 8 The distribution of the equivalent state of stress calculated after specific energy theory of maximum strain, Von Mises

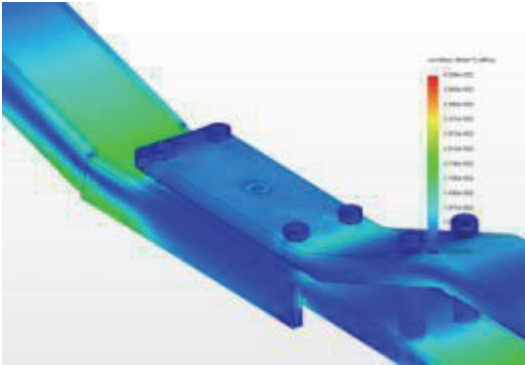


Fig. 9 Distribution the equivalent state of stress calculated after specific energy theory of maximum strain, Von Mises – detail image central area

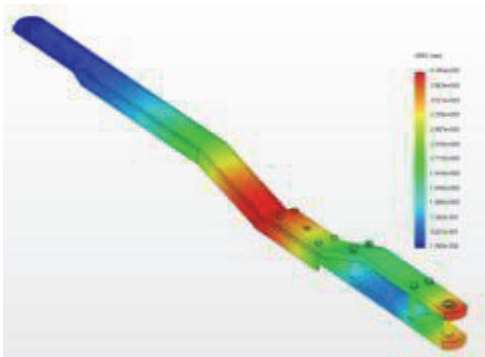


Fig. 10 The distribution of the total strain, in state, in *undeformed* state - overall picture

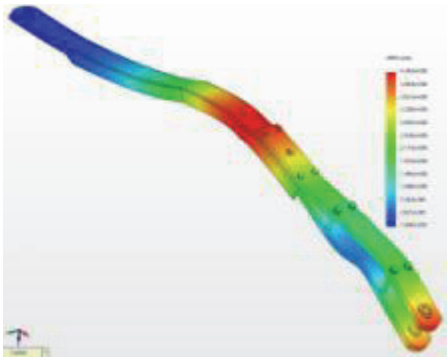


Fig. 11 The distribution of total strain, state in *deformed* state - overall picture

Determination of lifetime and safety coefficient at fatigue

The calculation of fatigue was conducted for a number of 1E7 stress cycles with constant amplitude based on von Mises equivalent stress distribution. The asymmetry coefficient of stress cycles is $R = 0.058$.

The calculation of the lifetime was carried out based on the limit cycle theory, Haigh diagram, for which was used the Soderberg schematization (Fig. 12).

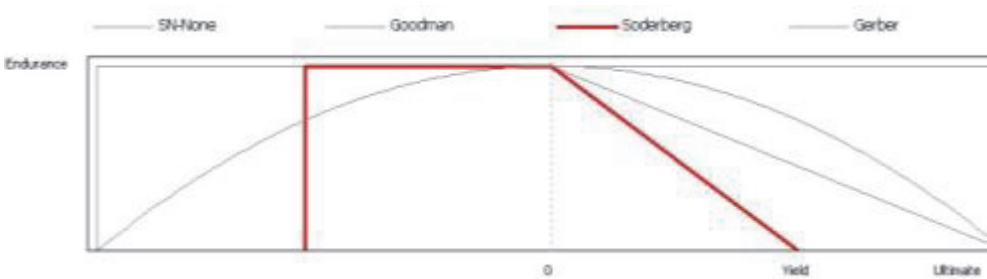


Fig. 12 The Soderberg schematization (the safety coefficient)



Fig. 13 The lifetime of the traction bar subjected to FEM analysis



Fig. 14 The safety coefficient of the traction bar

Based on the simulation performed in regime of variable request, the fatigue behavior of the traction bar assembly was established.

The verification of the resistance of the traction bar by experimental trials

Experimental attempt was conducted at the National Institute of Research - Development for Machines and Installations Designed to Agriculture and Food Industry - INMA Bucharest, on a specializing test stand (fig. 15).



Fig. 15 The installation for testing in simulated and accelerated regime type Hidropuls, overall view

In order for the results of the tests on the support stand to be accurate, the traction bar is fastened on the support stand within the Hidropuls installation simulating real conditions of fastening of its on the tractor (fig. 16 and 17).



Fig. 16 Overall picture during the fatigue tests of the traction bar on the stand within the Hidropuls installation



Fig. 17. Details on the fastening of the traction bar's heads on the stand within the installation type Hidropuls; a) Fixing the cylinder with the load cell at the bar, b) Fixing the other end of the traction bar on the stand

As it was presented previously calculated through simulation (fig. 13 and 14) the traction bar broke in two pieces (Fig. 18), after a number of 1805320 stress cycles, in the area with the highest concentration of stress - near the clamping of the two ends of the fork (in the area of weld of the reinforcing ribs, at 1070 mm from the axis of the clamping pin at the trailer). As it also results from the FEM simulation, in this area are found the highest strains (Fig. 10 and 11) and the equivalent stresses exceed the allowable stress value (Fig. 8).



Fig. 18 Overall picture of the area in which occurred the breakage to fatigue of the traction bar

CONCLUSIONS

Following the results obtained by simulation by FEM analysis or by experimental testing at stand can be drawn the following conclusions:

- Static calculation model elaborated in order to simulate the requests by adopting the computing assumptions presented, confirmed the endangered area in that appear the

maximum stress, which corresponds to the rupture zone. From this conclusion resulted a first confirmation of the correct choice of the calculation model;

- based on the phenomenon of fatigue simulation by finite element method it was calculated the lifetime expressed by the total number of cycles of 1798000 and after the experimental tests on stand this broke at a number of 1805320 complete cycles of traction request, resulting a percentage deviation of 0.5% between the numerical simulation and experiment, which confirms the correct choice of the calculation model;
- the cost price of the simulation is much more reduced compared to that of the experiment;
- calculation model thus elaborated can be used effectively to study the sustainability of new constructive variants of traction bars.

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INCREASING AGRICULTURAL MACHINERY ACTIVE PARTS DURABILITY BY HARDENING

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ABSTRACT

Active bodies of *soil tillage* machines are the most stressed parts and *they* wear during soil tillage, due to friction with the soil and *to the resistance* which they encounter while moving through the soil. Among the active bodies, coulters wear the most, which is why solutions were sought to easily change *them*, to increase their durability, for auto-sharpening, etc. This paper presents the behavior of the *coulters of a classic plough*, hardened by various methods, compared to a standard coulters, non-hardened. The results *were* obtained by *plowing* several hundreds of hectares, on the same type of soil, *with an plough* on which the coulters were mounted. The wear level was determined by weighing the plough share at the beginning of work and when demounting it, after having reached the maximal wear (it could not been used anymore).

Key words: *friction, plough, soil, surface, wear*

INTRODUCTION

A soil is more abrasive as it contains particles with high hardness, many times higher than the material from which the tool is made. This leads to premature wear of the tool, modification of its geometry and mass, especially that of the cutting part (which gets blunt), leading to significant increases in working resistance and fuel consumption [1, 2]. In addition, replacement and refurbishment works lead to decreased productivity and farming costs [7].

The active bodies of agricultural machinery are components that come into direct contact with the soil or with the agricultural materials on which they act [3]. Since these bodies are

subjected to variable loads of quite high values, wear intensity is much higher than other parts of the machinery, they are called high wear bodies [8, 9, 13].

Active bodies or high wear bodies of agricultural machinery are [3, 8, 14], shares to ploughs, knives to cultivators, hoes rotary and cutters, discs or the disc teeth, shares of beet and potatoes harvesting machines, driving enforcement of cereal grain harvesting machines, plant chopping knives to combine storage, rollers and hammer mill grinding blades and screw from conveyors.

The researches conducted in [8] showed that there are two main forces acting on active bodies: friction and impact. The action of these forces causes wear, which manifests in two distinct aspects, namely: wear of friction (slip) and wear impact (collision).

The inequality of these forces is based on the greater difference between the contact surface of inclusion into the matrix and surface of deformation or micro shaving into the cutter during the shaving process [10, 11, 12].

Also, the researches made have sought material analysis, treatment and construction, as well as new methods of wearing deposition [3], the behavior of new components used for hardening active bodies of tillage machinery [3, 17], the determination of mechanical properties and wear of materials [8] the characterization of new materials for solidification [15, 16], taking into account soil textures [3, 5, 6] and its humidity [4, 6], etc.

MATERIALS AND METHODS

First, checking of new reaction of bi-metal components was done in laboratory conditions, collecting test tubes from hardened areas (weld area) and not only, aiming to whether and what changes occurs in physical-mechanical characteristics and friction materials from subject area.

Test tubes were polished and their hardness was determined: HV2 Vickers hardness, Rockwell hardness HRC, respectively, by means of a *hardness-testing machine HMV Shimadzu*.



Fig. 1 Polished samples, on the friction side of the share

Shares were loaded welded form of alveoles with a new type of filler material - wire tubular composite core. Determination of the specific friction properties (coefficient of friction, wear strength, stability of friction coefficient) was performed on a special stand (fig. 2), which allows measurement of the required calculation to determine these sizes.



Fig. 2 Stand for testing samples to friction; 1. cast-iron friction disc; 2. engine- disc gear; 3. weights set to realize the pressure; 4. sample holding device

For each sample were made different speed regimes respectively loads applied to try to simulate real working conditions in the field: different work speeds and soil resistance:

- mode speed: 100 rev / min.; 200 rev / min and 300 rev / min;
- load on the specimen under test: 8.535 daN and 12.46 daN.

To highlight the wear behavior of new materials in operation, they were applied to 15 shares which were mounted on the plough bodies of 5 agricultural ploughs, hardened with:

- tubular wire with large carbides inside (S);
- coated electrodes – with small carbides inside (E);
- cross deposit to cutting edge (T) by welding on one of sides;
- longitudinal deposit to the cutting edge (L) by welding on one of sides.

Shares mounted on plough bodies were introduced into the field to perform works (autumn plowing) in an agricultural association in Tunari, Demieni village (Ilfov County, Romania), grouped into five different ploughs.

Shares were weighed before and after being used for ploughing, to observe the loss of material by wear.

The machines worked on the same soil: reddish brown (texture depending on profile, with a higher clay percentage, average and large granular structure in upper horizon and very well prism-shaped features ARGIC – Bt horizon) areas between 15 and 80 ha, helping us to draw some conclusions on the various degrees of wear.

Shares with different types of deposits, mounted on different ploughs have been introduced into fields, each of them being used in work on different surfaces (Table 1).

Table 1 Effective wear depending on area worked

No. of share	Share type	Deposit type	Code plough	No. ha worked
1	B5	EL1	P5	15 ha
2	B1	ET6	P5	
3	BB1	EL5	P5	
4	A2	SL5	P2	40ha
5	A4	STn	P2	
6	B6	M	P2	
7	BB4	EL3	P4	50 ha
8	B4	ET6	P4	
9	B3	ET6	P4	
10	BB3	EL4	P3	60 ha
11	BB2	EL2	P3	
12	B2	EL2	P3	
13	A3	SL5	P1	80 ha
14	A6	STn	P1	
15	A5	M	P1	

No. - (1 6) the number of layers (cords) of successively applied weld; the no.> 5 using "n"

RESULTS

The researches concerning the operational behavior of bi-metal components constituting the agricultural machinery (shares of ploughs) have sought the determination of the physical and mechanical characteristics and wear, and how the plough coulters interacting with the soil, shall be subject to wear.

A total of 16 plough shares were hardened with new materials in the cutting edges, pursuing in this way both self-sharpening effect of the operation as the reduce of total wear of those active working bodies, deposits giving better resistance abrasion under pressure.

These shares were mounted on ploughs from some farmer's machineries and homeowners associations to be placed in the field to work plowing.

By welding were welded two types of material:

1. coated electrodes - with small carbide;
2. tubular wire comprising large carbides.

These two materials were deposited longitudinally or transversely to the cutting edge of the coulter, as shown in figures 4 and 5, in figure 3 being shown the control share.



Fig. 3 Share arm (no deposit welded) - M



Fig. 4 Share, tubular wire rack deposits - STn



Fig. 5 Share, deposits longitudinal five layers with coated electrodes - EL5

Shares were stamped with the letters A, B and BB respectively numbered 1-8 (Table 1), marked with the letter A were hardened tubular wire, B and BB respectively - with coated electrodes (Fig. 6 and 7), except A5 and B6 are witnesses other than hard rubber (fig 3), being left thus to have a benchmark for comparison.

To determine the wear of shares (loss of material by wear) these coulter were weighed before working the soil, respectively to their completion (Fig. 3, 4 and 5).

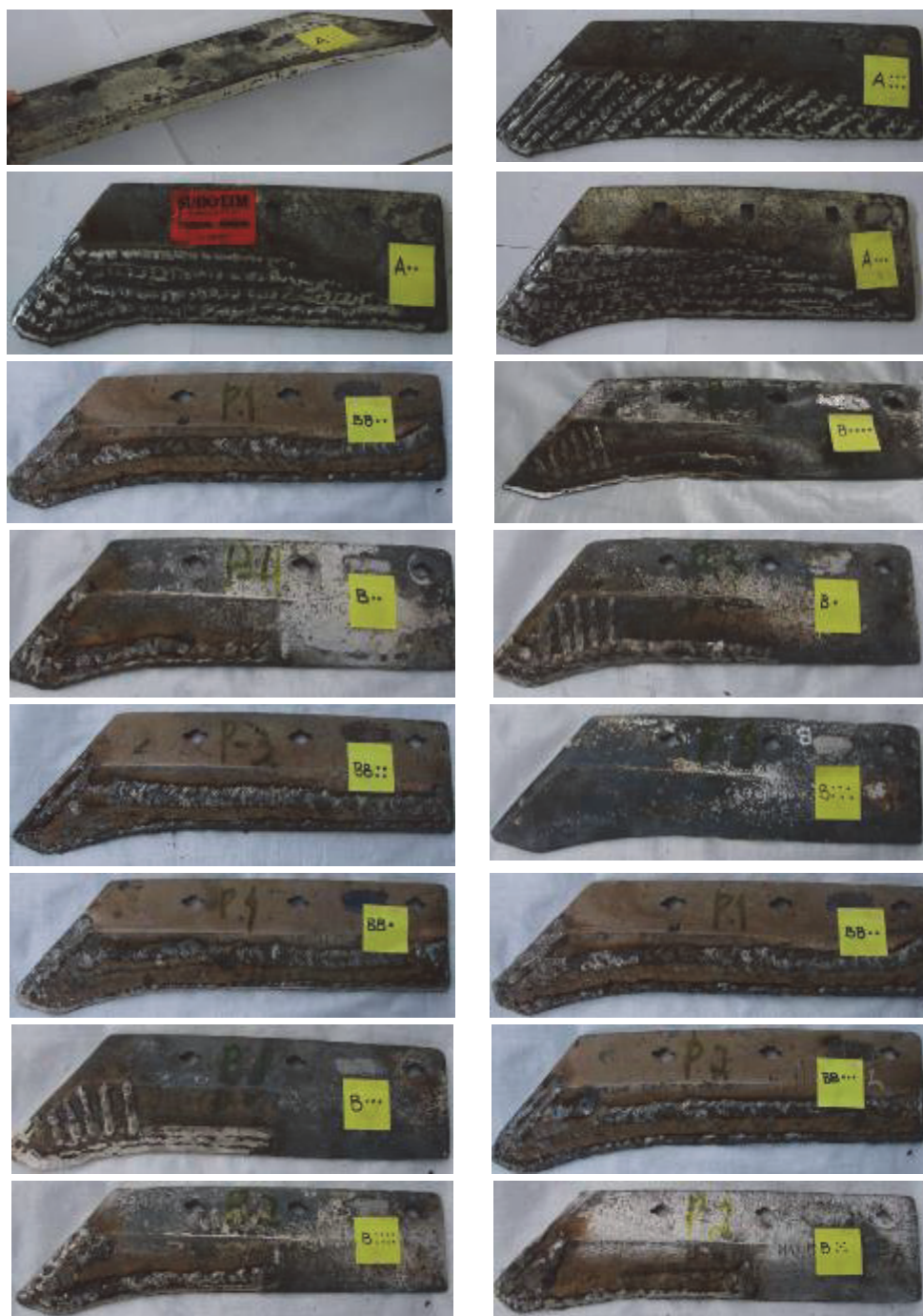


Fig. 6 Shares hardened deposits and coded to be pursued it at work



Fig. 7 Combined share mounted on the same plough P1

Ploughs worked on the same reddish-brown forest different soil surfaces, which not prevents us to draw some conclusions on the various degrees of wear, as they were mounted combined (fig. 8) in the same plough, shares with different types of deposits and (Table 1).



Fig. 8 Installing the shares on the plough body before being placed in the soil

The shares mounted on plough bodies were introduced into the field to perform work (autumn plowing) in an agricultural association in Tunari, Demieni village, where shares were clustered and assembled into five different ploughs (fig. 9, 10).



Fig. 9 One of the five ploughs to which the shares were mounted prior to insertion into the plowing



Fig. 10 One of the ploughs that have shares mounted in it

Table 2 Data obtained for shares submit analyzes the wear at a working speed of 1.6 ms^{-1}

Share no.	Share type	Deposit type	Code plough	Weight before work (plowing) [g]	Weight after working [g]	Mass difference (actual wear) [g]	No ha worked	Comments
1	B5	EL1	P5	4262.3	4119.8	142.5	15 ha	Shares hardened longitudinal charge (EL1) performed best, with the lowest wear
2	B1	ET6	P5	4830.5	4679.7	150.8		
3	BB1	EL5	P5	5324.6	5134.0	190.6		
4	A2	SL5	P2	5266.7	5085.6	181.1	40ha	Share hardened tubular wire (SL 5) uploaded longitudinal behaved better than transversely loaded coulter or witness.
5	A4	STn	P2	5231.1	5038.6	192.5		
6	B6	M	P2	4935.6	4683.5	252.1		
7	BB4	EL3	P4	5331.0	5106.6	224.4	50 ha	Share longitudinal loaded (EL 3) along the cutting edge performed better than transverse loaded one.
8	B4	ET6	P4	4793.7	4470.2	323.5		
9	B3	ET6	P4	4774.6	4403.2	371.4		
10	BB3	EL4	P3	4920.4	4637.3	283.1	60 ha	Surface covered Share with 4 layers (EL 4) has worn less than 2 layers coulter
11	BB2	EL2	P3	5818.3	5501.1	317.2		
12	B2	EL2	P3	5127	4805.3	321.7		
13	A3	SL5	P1	5342.0	5006.8	335.2	80 ha	Alternative deposition Share along the cutting edge (SL 5) is worn out less than the other.
14	A6	STn	P1	5463.9	5107.7	356.2		
15	A5	M	P1	5440.1	5079.7	451.2		

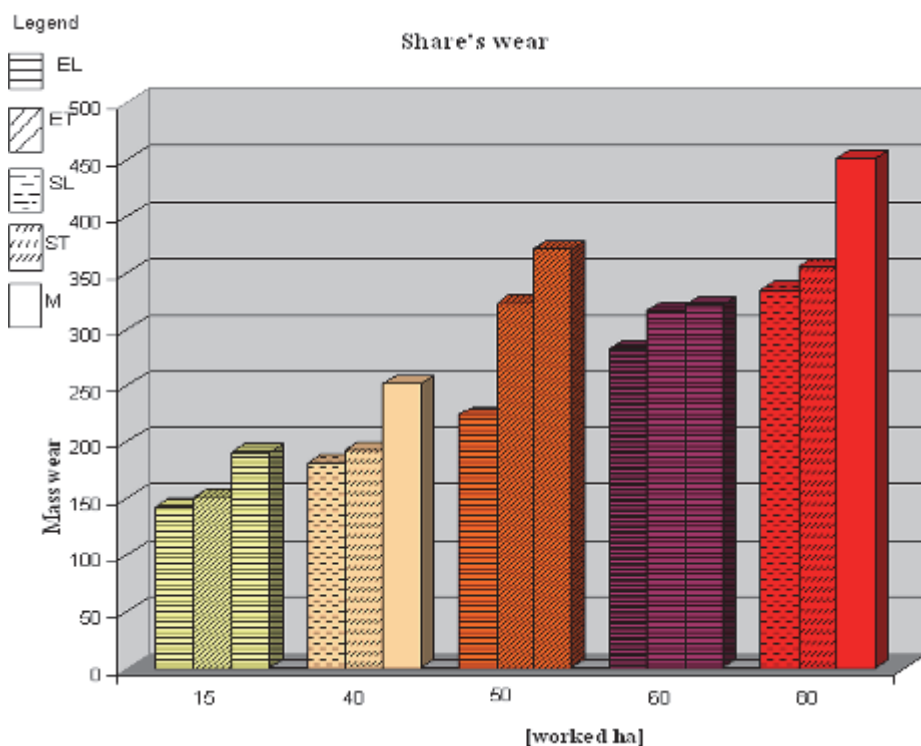


Fig. 11 The 15th shares wear from five ploughs

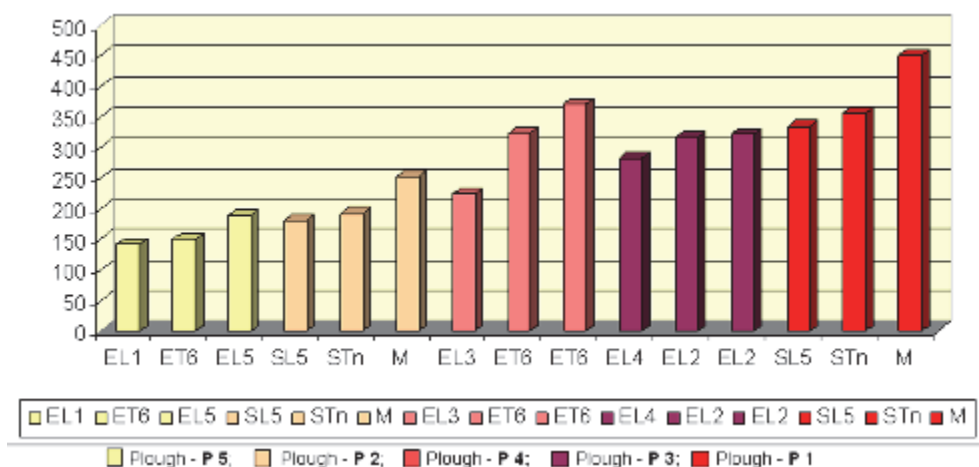


Fig. 12 Evolution of weight loss [g] of the 15 shares mounted on ploughs, depending on the type of deposit

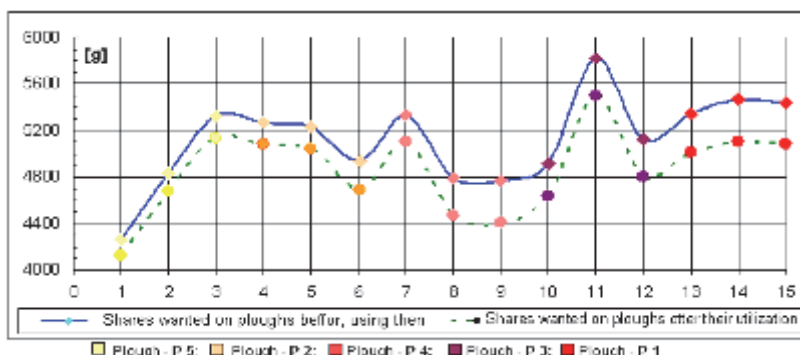


Fig. 13 Evolution of weight ploughs mounted shares before being introduced into the work and after work (coulters 1÷3: plough P 5; coulters 4÷6: plough P 2; coulters 7÷9: plough P 4; coulters 10÷12 : plough P3, coulters 13÷15: plough P 1)

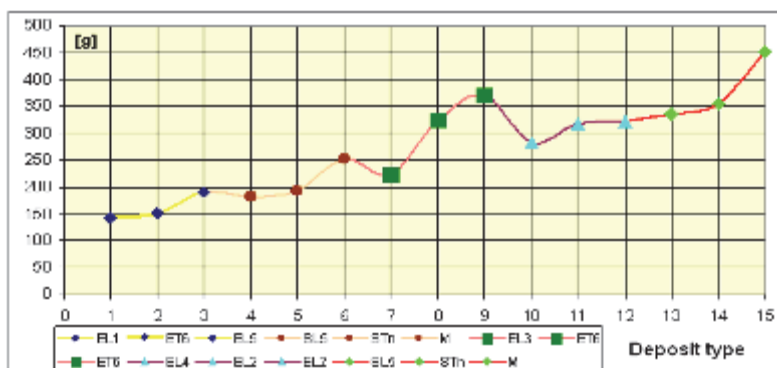


Fig. 14 The evolution of weight loss of the 15 shares mounted ploughs (coulters 1÷3: plough P 5; coulters 4÷6: plough P 2; coulters 7÷9: plough P 4; coulters 10÷12: plough P 3; coulters 13÷15: plough P 1)

Distribution of the 15 hardened shares on the 5 ploughs is shown in Figure 11 and the evolution of weight loss of 15 shares mounted on ploughs, depending on the type of deposit is shown in Figure 12. In figures 13 and 14 are represented the wear evolution of the 15 shares before entering in ploughing and after working 15 ha / 40 ha / 50 ha / 60 ha / 80 ha, for each type of plough.

CONCLUSIONS

After using these shares in the field, mounted on five different ploughs to an agricultural association in Tunari, Demieni village, it resulted that where they worked different surfaces: 15; 40; 50; 60 and 80 ha, the hardened shares both coated electrodes - small carbide

and carbide wire large hollow interior were less worn (between 20÷40%) than the control share. Thus:

- For all hardened shares, the least have used the hardened with longitudinal weld applied to the loaded than transversely;
- In the case of hardened shares (3) with longitudinal seams, that with a higher coverage area respectively four layers (BB3- EL4) was used less about 10%;
- In the case of using a control shares (other than hard rubber), this wear about 30% more than the other two hardened, mounted on the same plough;
- The costs for hardening by this method are smaller comparable to those of hardening conventional methods.

Abrasion resistance increases with the hardness of the material, the deposits having a hardness of about 30 HRC compared to the control sample which is about 5 HRC. Both submitted materials being very hard, give good results compared to the base material of the cutter blank.

During work, shares were not reground, the side without no deposit wears easier, they will always have a good angle.

ACKNOWLEDGEMENT

This paper has been financially supported within the project entitled „SOCERT. Knowledge society, dynamism through research”, contract number POSDRU/159/1.5/S/132406. This project is co-financed by European Social Fund through Sectoral Operational Programme for Human Resources Development 2007-2013. *Investing in people!*”

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AGROTECHNICAL AND ENERGETIC CHARACTERISTICS OF NEW DESIGNED SUBSOILER

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SUMMARY

Deep loosening or deep subsoiling aims to achieve a radical change in the characteristics of the soil in the compacted and impermeable layer, thus increasing the water storage capacity, creating the conditions for normal aeration and soil heating, respectively the organic activation of soil processes. The paper presents experimental research performed with experimental equipment for soil deep loosening removing the impermeable soil layer (hardpan) and for allowing water infiltration in the upper layers, in order to determine the qualitative indices obtained with this equipment.

Key words: subsoiler, soil, loosening

INTRODUCTION

Since climate change scenarios predict in most semi-arid regions of the world, an increase in temperature, changes in precipitation patterns and longer drought periods that lead to soil degradation, in Europe are carrying out researches on soil respiration which is one of the main processes responsible for the loss of organic matter. The studies carried out have shown that soil degradation could alter the carbon balance of these ecosystems through changes in temporal dynamics of soil respiration and plant productivity, which have important negative consequences for the functioning of ecosystems in time [10].

In Romania, the main process of soil degradation, by extension and socio-economic impact, is the erosion by water, which along with landslides affects over 7 million ha of agricultural soil. The second important factor in soil degradation is the periodic moisture excess which affects 3.8 million ha of agricultural soil, while frequent droughts excess manifests on approx. 7.1 million ha of agricultural soil [14].

In this context, through the work presented is proposed a new approach of soil works in the arable substrate specific to heavy and compacted soils, affected alternatively by excess and deficiency of moisture and also for other types of soils which show limitations of production capacity due to salinization, alkalisation, pollution etc.

Studies on the mechanization technology for deep loosening and aeration of defective soil, aspects concerning the soil penetration resistance after deep soil loosening work and energetic consumption of the deep soil loosening work [1, 2, 3] have highlighted the need for deep loosening works at least once every 4 years.

In order to reduce the resistance during operation and the fuel consumption, researches were developed for unifying the resistance expression of machines designed to soil tillage with applications in their working regime optimization, and also structural analysis of resistance structure as a component of equipment with active working parts driven to deeply loosen the soil [6, 7, 8].

MATERIALS AND METHOD

Experimental researches in the field were made on agricultural soil on which wheat was harvested, belonging to CRINA Bărcănești Agricultural Enterprise, in Olt County (Romania), in order to determine the qualitative and energy indices, using a CASE INTERNATIONAL 7140 tractor in aggregate with the equipment for soil loosening.

Considering that the soils in this area have a structure which recommends them as medium-heavy soils and the equipment has 5 bodies, the recommended energy source should be about 200 [HP], in this case being used a tractor of 143.5 kW.



Fig. 1 Tractor with coupled experimental subsoiler

The subsoiler (fig. 1), that has been used in experimental research, consists of the following main assemblies:

- chassis to ensure the coupling of equipment in three points to the rods of the tractor's hydraulic lifter, catching of the 5 active bodies for deep soil loosening and the support of nutrient application equipment;
- active parts with reversible chisel knives and special knives for hardpan removal;
- claw rollers placed behind the active parts for shredding and easy levelling of the processed soil;
- left / right support wheels to provide adjustment and limitation of working depth of the active parts.

The main technical characteristics of the equipment used in the experiment are:

- Number of loosening bodies: 5;
- Number of shredding bodies: 2;
- Maximum working depth: 0.6 m;
- Working width: 2.3 m;
- Mass: 2040 kg.

Components of new desined subsoiler for the loosening compacted soils related to the adjustment system of transport height and the elastic system for following soil surface configuration of rollers batteries were made in accordance with [4] and [5].

To determine the *agrotechnical and energetic characteristics* in the field were also used the following devices of measuring, control and data acquisition:

- Mechanical timer;
- Apparatus for determining fuel consumption;
- SC 900 penetrometer produced by Spectrum Technologies Inc;
- HH2 moisture meter produced by Delta-T Devices;
- Electronic balance;
- Device for measuring the wheel speed;
- Resistive strain transducers (strain gauges);
- Digital measuring system with data acquisition MGCplus [7];
- Soft for data processing GlyphWorks-nCode ICE-flow [8].

In order to determine the qualitative work indices, strain gauges were glued on the lateral and central rods (surfaces have been cleaned and polished before gluing), fig. 2, then was mounted the apparatus for determining fuel consumption (flowtronic type) on the tractor, strain gauges and the system were calibrated, and the soil was divided in plots of 50 m length.



Fig. 2 Strain gauges glued on the tractor linkage



Fig. 3 Voltage inverter mounted between tractor batteries and data acquisition system

Determination of draft forces strength was performed using resistive strain gauge transducers mounted on the three-point linkage of the tractor unit, and the data acquisition was performed using a laptop and a digital measuring system with data acquisition type MGCplus, equipped with Cadman special software for acquisition, processing and filtering of raw data. The system was powered from the tractor battery using a voltage inverter (fig. 3).

The GlyphWorks-nCode ICE-flow software enabled faster data processing and graphical drawing of their minimum, average and maximum values.

RESULTS AND DISCUSSION

Experiment in the field aimed to determine the following indices of qualitative work:

- The degree of soil compaction;
- Loosening degree;
- Average working depth;
- Average working width.

Draft power, P_{tr} is:

$$P_{tr} = \frac{F_{tr} \times v_l}{3600}, [\text{kW}] \quad (1)$$

where: F_{tr} is measured in [N] and v_l in $[3.6 \times \text{ms}^{-1}] / [\text{kmh}^{-1}]$.

The following indices were determined with subsoiler coupled with 143.5 kW tractor.

The degree of soil compaction was calculated according to the following equation:

$$G_T = \frac{PO_{\min} - PO_e}{PO_{\min}} \cdot 100 \quad [\%] \quad (2)$$

where: $PO_{\min}$ – minimum porosity required to a soil suitable for crops [%];

PO – the effective porosity of the soil [%].

Porosity was calculated according to the following equation:

$$PO_t = 100 \left(\rho - \frac{\rho_A}{\rho} \right) \quad (3)$$

where: ρ_A – bulk density $[\text{g/cm}^3]$ is ρ – density $[\text{g/cm}^3]$.

From the above equation it results that the degree of soil compaction that determines the need for loosening is a characteristic of the physical condition of the soil at any given time. It was determined the porosity of a Chernozemic soil with a mollic horizon (Am) with chromes ≤ 2 (dark colours, blackish, dark brown) in the area of CRINA Bărcănești agricultural society in Olt County.

Table 1 presents the determined values of the degree of soil compaction in horizon Am.

Table 1 Degree of soil compaction

	Depth [cm]	$P_{\min}$ [%]	P_e [%]	G_T [%]
Horizon Am	0...24	62	48	22,58
	24...42	56	44	21,42
	42...57	50	40	20,00

Loosening degree was calculated according to the following equation:

$$G_{as} = \frac{\sum_{i=1}^n \frac{h_1 - h_2}{h_1}}{n} \times 100 \quad [\%] \quad (4)$$

where: h_1 is the ordinate at a certain point on the ruler at the soil surface before the passage of technical equipment [cm];

h_2 – the ordinate at the same point on the ruler at the soil surface after the passage of technical equipment [cm];

n – number of measurements.

Table 2 presents the determined values of the degree of soil loosening.

Table 2 Degree of soil loosening

No. of repetition	h_1 [cm]	h_2 [cm]	G_{as} [%]
1	181	151	18.26
2	204	167	
3	198	161	
4	189	157	
5	194	154	

Average working depth was determined by measuring the distance between soil surface and the bottom of the furrow left by the active body and was calculated according to the following equation:

$$a_m = \frac{\sum_{i=1}^n a_i}{n} \text{ [cm]} \quad (5)$$

where a_i is the measured working depth, cm and n – number of measurements.

The standard deviation of working depth was calculated according to the following equation:

$$\sigma = \pm \sqrt{\frac{\sum_{i=1}^n (a_i - a_m)^2}{n - 1}} \text{ [cm]} \quad (6)$$

The variation index of working depth was calculated according to the following equation:

$$V_a = \frac{\sigma_a}{a_m} \times 100 \text{ [%]} \quad (7)$$

Table 3 presents the determined values of average working depths.

Table 3 Average working depth

No. of repetition	a_i [cm]	a_m [cm]	V_a [%]
1	58.2	60.16	1.24
2	61.4		
3	59.2		
4	60.8		
5	61.2		

Average working width was calculated according to the following equation:

$$B_m = \frac{\sum_{i=1}^n B_i}{n} \text{ [m]} \quad (8)$$

where: B_i is the measured working width, m and n – number of measurements.

The standard deviation of working width was calculated according to the following equation:

$$\sigma_B = \pm \sqrt{\frac{\sum_{i=1}^n (B_i - B_m)^2}{n-1}} \text{ [cm]} \quad (9)$$

The variation index of working width was calculated according to the following equation:

$$V_B = \frac{\sigma_B}{B_m} \times 100 \text{ [%]} \quad (10)$$

Table 4 presents the determined values of the average working width.

Soil moisture measured in the plot in which the assays have been performed (fig. 3). ranged between: 36÷44% and the penetration resistance (fig. 4) had a maximum value of 980 kPa (15 cm); 1286 kPa (30 cm) and 1684 kPa (45 cm), which are very high values for both moisture and penetration resistance, due to the fact that it rained about a week before but mostly because the soil in that plot was not subsoiled for over 20 years.

Table 4 Average working width

No. of repetition	B_i [cm]	B_m [cm]	V_B [cm]
1	232	231,2	4,14
2	234		
3	228		
4	226		
5	236		



Fig. 3 Measurement of soil moisture in the plot where the quality indices were determined



Fig. 4 Measurement of penetration resistance in the plot where the quality indices were determined

To determine draft force (fig. 5) in operation, were used the MGCplus acquisition system, the soil loosening equipment being set to the maximum working depth of 60 cm.

The variation of the tractive force measured at the rods of the tractor, at the adjusted working depth of 60 cm is shown in figures 6 and 7.



Fig. 5 Soil surface after subsoiler pass; tractor with coupled subsoiler



Fig. 6 Variation of draft force at working depth of 60 cm

From the data processing program using GlyphWorks-nCode ICE-flow program it resulted the minimum value of draft force ($F_{tr \min} = 22.4 \text{ kN}$), average ($F_{tr \text{ med}} = 51.84 \text{ kN}$) and maximum values ($F_{tr \max} = 75.71 \text{ kN}$) for working depth of 60 cm (fig. 7).

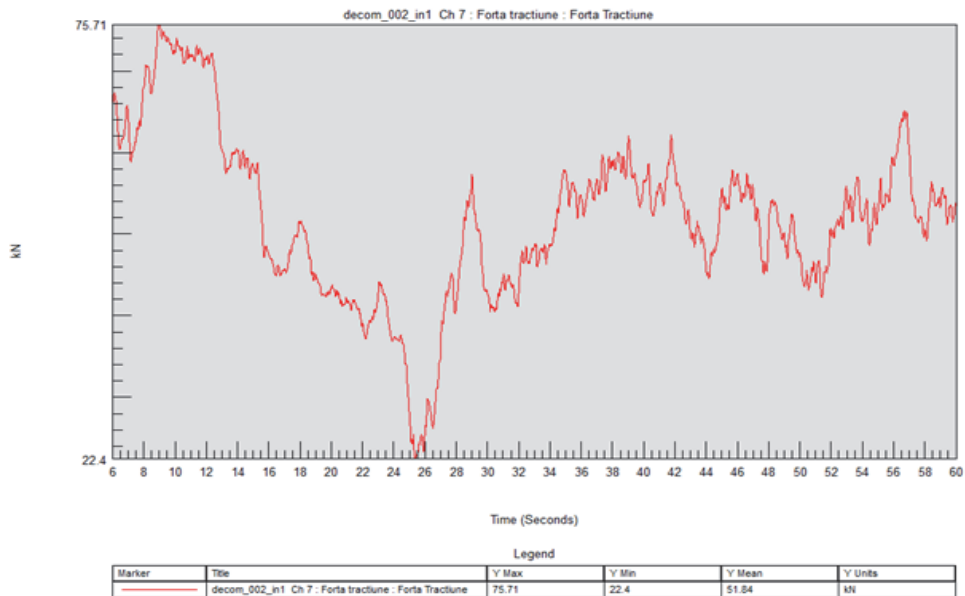


Fig. 7 Minimum, average and maximum tractive force at working depth of 60 cm

For the 3 speeds of the subsoiler coupled with the tractor, variation of energy indices was determined the (fig. 9).

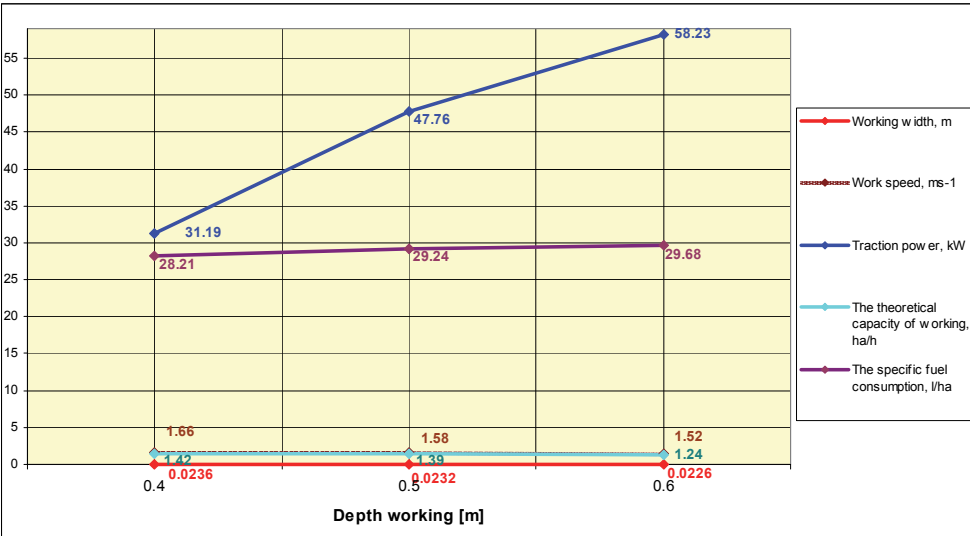


Fig. 8 Variation of indices for three velocities

CONCLUSIONS

Under the conditions of an alluvial leached chernozem type of soil, located in the area where the experimental research were carried out, the technical equipment in aggregate with CASE INTERNATIONAL 7140 tractor performed the soil loosening with qualitative indices adequate to agrotechnical requirements, thus:

- degree of loosening: 18.26 %;
- coefficient of working depth variation: 1.24 % at average working depth of 0.6 m;
- coefficient of working width variation: 4.14 % at average working width of 2.3 m.

Under the same conditions, the equipment has achieved the following energy indices:

- working speed:
 - 1.66 m/s to working depth of 0.4 m;
 - 1.58 m/s to working depth of 0.5m;
 - 1.52 m/s to working depth of 0.6 m.
- draft power:
 - 31.19 kW at working depth of 0.4 m;
 - 47.76 kW at working depth of 0.5 m;
 - 58.23 kW at working depth of 0.6 m.
- Work rate for the effective working time:
 - 1.42 ha/h to working depth of 0.4 m;
 - 1.39 ha/h to working depth of 0.5 m;
 - 1.24 ha/h to working depth of 0.6 m.
- fuel consumption per hectare:
 - 28.21 l/ha to working depth of 0.4 m;
 - 29.24 l/ha to working depth of 0.5 m;
 - 29.68 l/ha to working depth of 0.6 m.

Energy indices (working speed, draft power) achieved by the subsoiler coupled to CASE INTERNATIONAL 7140 tractor showed a good stability during operation, and energy consumption achieved at various working depths are comparable to those achieved by similar equipment in operation.

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STATE OF ART APPROACH TO VIBRO-COMBINATORS SOIL TILLAGE IMPLEMENTS CONSTRUCTION

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SUMMARY

The advantages of using vibro-combinators are: Required preparation of seedbed in difficult working conditions and preservation of soil moisture. Such important factors can ensure fast, uniform and early germination of seeds, these requirements standing at the basis of abundant harvests. Advanced methods of numerical calculus (finite difference method, finite element method, modal analysis) began to be successfully used in recent years for the analysis of stress state of the resistance structure and working bodies for vibro-combinators, and for the study of soil behavior at the interaction with the working bodies.

Key words: *Vibro-combinator, soil-tillage interactions, tillage tool, FEA, DEM*

INTRODUCTION

Nowadays, humanity is facing a major controversy over the choice of appropriate technology of soil tillage. It is the time that is required an intelligence choice between conventional technologies (classical) for seedbed preparation, assuming an intense mechanical processing of soil, which affects soil structure and soil organic matter, and the

conservative tillage technologies for seedbed preparation, which removes these disadvantages in terms of an accepted decrease of the production. In figure 1 is presented the interaction between soil organic matter and biodiversity under different agricultural systems (M. Pisante et al. 2010).

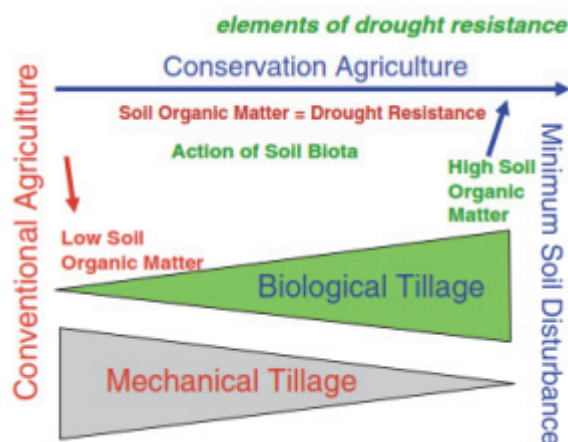


Fig. 1 Soil organic matter under different tillage systems (M. Pisante et al. 2010)

Seedbed preparation for crop establishment (sowing) is one of the most important agricultural works, as is done with high energy consumption and high costs. The quality of this work influences in large measure the germination of crop and the productivity that can be obtained per hectare. Therefore, at present, there is different equipment from the ones found in classical cultivation technologies, which in single pass can achieve tillage with minimum energy consumption, thus creating optimal conditions for sowing and for obtaining higher yield without soil degradation (J. Benites 2000). These devices are called combinator. Of all the existing combinator, most performant are the vibro-combinators.

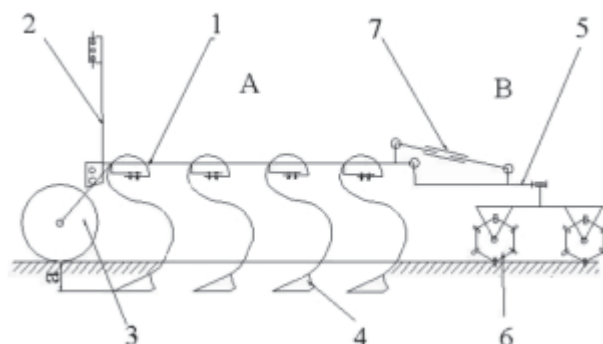


Fig. 2 General scheme of a vibro-combinator (St. Caproiu et al. 1982)

Generally, combinator consists of a vibro-cultivator A (cultivator for total processing of soil), composed of: frame 1, coupling device at the power source 2, wheels for limiting of working depth 3, soil loosening bodies 4, and a helix harrow B, which consists of frame 5, two rodrotors 6, and horizontality adjustment system 7 (Fig. 2). Worldwide, more and more prestigious companies have incorporated into the range of products such vibro-combinators.

THE CURRENT STATE REGARDING THE CONSTRUCTION OF VIBRO-COMBINATOR

Most used classical types of agricultural combinator structures are presented in Figure 3. First area (I) is destined for soil leveling and for the control of working depth. Levelling boards with steeples manual height adjustment is standard equipment. As option a robust and very effective crossboard is available (Fig. 4) [22,23,24,25]. It can be supplied with spindle adjustment or a cylinder for hydraulic adjustment from the tractor seat. Both the levelling boards and the crossboards are sectional constructed to follow the ground contours better. Cage roller is fitted in the front, just after the leveling equipment, for better depth control and to avoid the risk of soil sticking. The flexible bolt-on construction gives the possibility to move the roller in the middle of the tine sections if wanted.

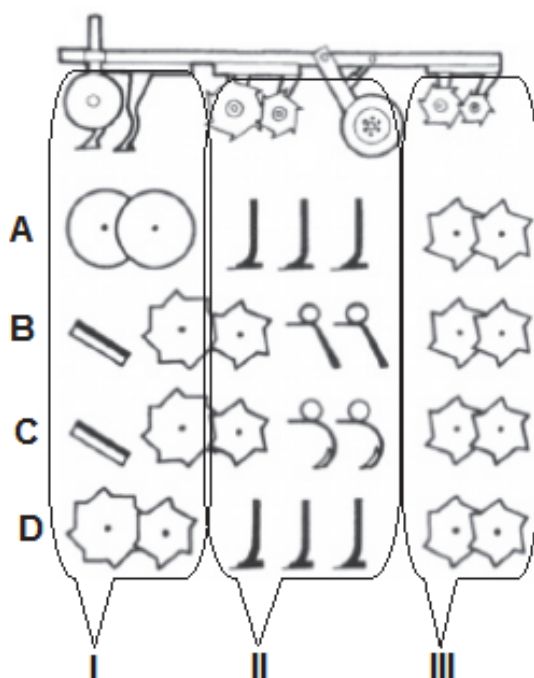


Fig. 3 General scheme of combinator structure



Fig. 4 Variants of systems used for ground leveling and adjusting the working depth [22,23,24,25]

In the IInd area (Fig. 3) are found the working bodies for soil tillage through crushing or cultivating. Mostly, in modern cultivators, in this area are found four rows of effective tines which aim to give optimum work. The two first rows, with tines, have bigger distance of 500 mm in order to allow optimum soil flow even in heavy soils with a lot of clods. The two next rows, with tines, are fitted with a distance of 250 mm in order to get more breaking and leveling effect. The tines are adjusted by spindles. It is possible to adjust with different angles on the front and rear section [22,23].

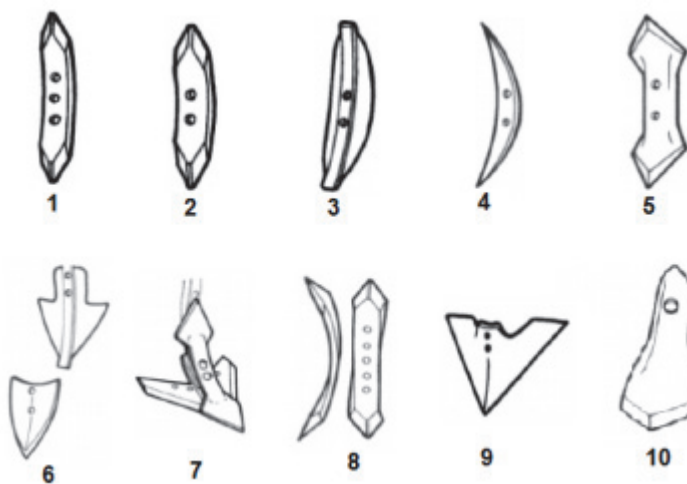


Fig. 5 Types of vibro cultivators working shares [7,22,23,24,25]

In Figure 5 are presented various technical solutions of working bodies for vibro-cultivator [7,22,23,24]. These can be: 1-narrow reversible share (for heavy and hard conditions, as well as deep loosening), 2-standard reversible share, 3-removed reversibly share, 4-reversible claw (ideal for working of heavy and hard soils, where the soil is crumbled ideal, loosened and vented), 5-double heart share (excellent penetration into hard

soils and outstanding crumbling in heavy conditions, and ideal for mid-depth work), 6-ridge share, 7-broad duck foot share (excellent incorporation in free-flowing soils and at low working depths, as soil can be lifted well to the surfaces), 8-share with cutting plate (supports crumbling in heavy soils through additional fragmentation of clods), 9-simple duck foot share, and 10-narrow duck foot share.

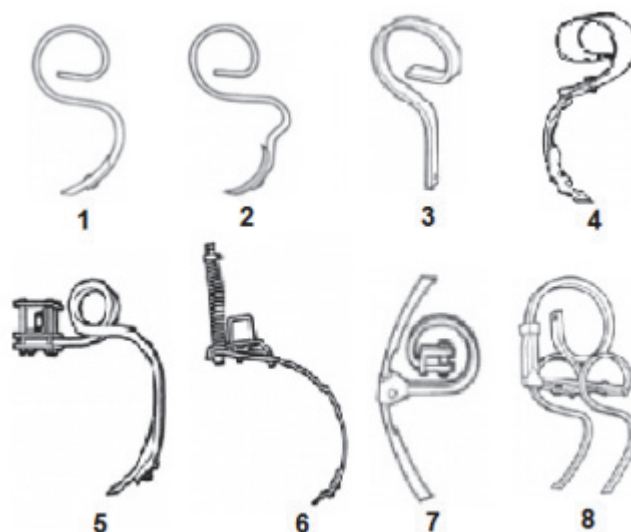


Fig. 6 Variety of tines for different soil conditions [7,22,23,24,25]

There is a great variety of tines for all conditions. Although there are rigid tines, currently the most used tines are the flexible ones (Fig. 6). These tines can be: 1-simple curved elastic, 2-double curved elastic, 3-straight curved, 4-elastic with wide lamellar tine, 5-double spiral elastic, 6-elastic on tine with spring, 7-reversible simple curved, 8-on auxiliary elastic tine [4,22,23,24,25]. Vibrating operation creates self-cleaning effect, prevents blockages and facilitates penetration in hard soils.

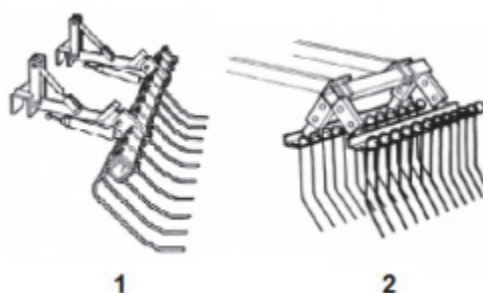


Fig. 7 Variety of tines for different soil conditions [7,22,23,24,25]

The IIIrd area (Fig. 3) of the combinators designed for crumbling and consolidation. At the rear of the combinator, a finger harrow or a single or double roller is finishing the job. The finger harrow can be rigid or with spring pressure (Fig. 7).

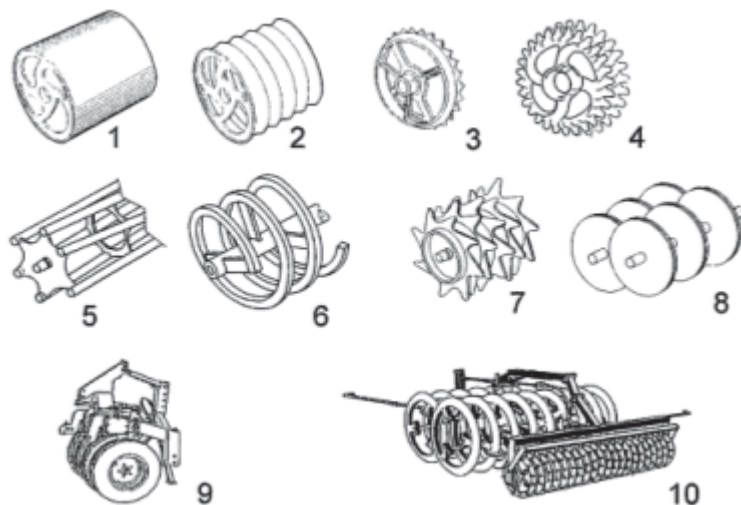


Fig. 8 Various types of rollers (C. Cedra 1991)

Rollers serve mainly for re-compaction, levelling and crumbling. At the same time, their task is to create a better contact between seeds and soil. Furthermore, they can be used as a means of spreading the tractor weight evenly across the whole width of the vehicle. Usually, rollers should be used under dry conditions since wet soil will clog them easily unless scrapers are used to clean them permanently (CIGR Handbook of Agr. Eng. 1999). According to their form, rollers can only compact the surface or act at a certain depth if they are shaped to penetrate through the topsoil. Many different forms are available (Fig. 8), namely: 1-plain, 2-grooved, 3-Cambridge, 4-Crosskill, 5-cage, 6-spiral roller, 7-toothed packer, 8-disk roller, 9-tyre furrow press, 10-conventional (Land packer) or furrow press with Crosskill roller (C. Cedra 1991). Among them, the furrow press should be noted, which is used directly after ploughing in order to give back to over-loosened soils optimum porosity and to make them trafficable again.

Advanced methods of numerical calculus (finite difference method, finite element method, modal analysis) began to be successfully used in recent years for the analysis of stress state of the resistance structure and working bodies for vibro-combinators, and for the study of soil behaviour at the interaction with the working bodies. The latest research in this direction are oriented toward computer-assisted analysis of how to distribute the stress in the body work, the tines and the strength of the equipment. The finite elements method (FEM) is used in order to study the bodies with a complex shape, providing numerical solutions for different physical characteristics when analytical solutions are impossible or very difficult to obtain. The finite element analysis (FEA) is used within this method (I. Tenu et al. 2012).

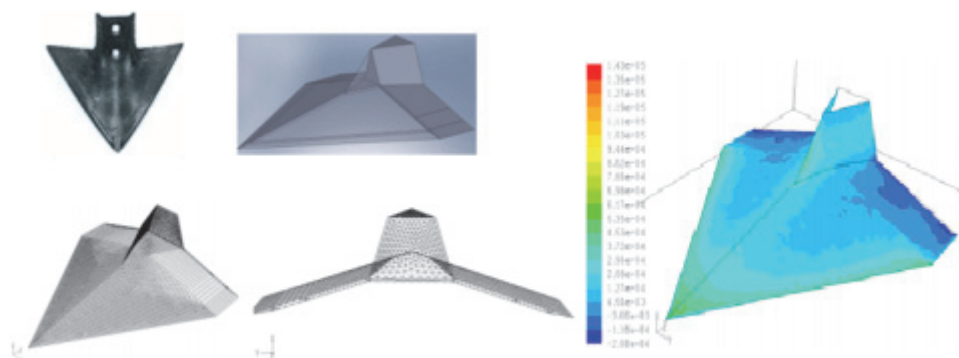


Fig. 9 Sweep rake changes due to soil resistance (I. Tenu et al. 2012)

Analysis of stress distribution in the body it is found in several recent works. Figure 9 presents a study of the Sweep rake changes due to soil interaction (physical model, meshed model and normal pressure distribution on the surface of the working).

THE CURRENT STATE REGARDING THE WORKING PROCESS OF VIBRO-COMBINATOR

In figure 10 is presented the general working scheme of a combinator destined for seedbed preparation (seedbed preparation devices). This machine first performs a levelling action by a skimming bar together with some crumbling by the first roller, which is equipped with cutter bars. This action is followed by a light cultivator, which breaks the surface and loosens the soil. These implements are followed by a second crumbling and leveling unit.

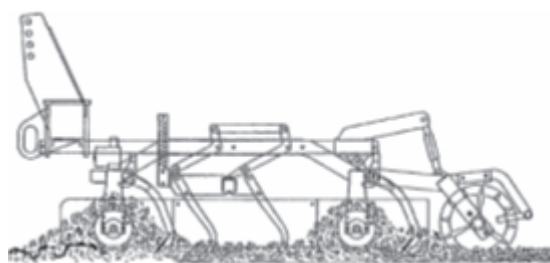


Fig. 10 Combined seedbed preparation devices (CIGR Handbook of Agr. Eng. 1999)

The last tool is a crosskill roller for recompaction. Such a unit can create a rather specific seedbed for most crops, depending on the depth adjustment of the single implements, the number and kind of implements, and the working speed. Working widths of 4 m and more are possible, thus creating very powerful machines for high performance. Especially on lighter soils and under favourable conditions (correct moisture content for tillage), these

machines form a rather effective and economical way for seedbed preparation. When several implements are combined, the limitations of the soil conditions are less severe as the machine acts like several passes of a single implement (CIGR Handbook of Agr. Eng. 1999).

As it results from the research conducted in the last years, the effect of combined machine was similar with twice disking on bulk density. The results of mean weight diameter proved that combine machine was slightly more effective than twice disking in shallow soil layer (A. Javadi and A. Hajiahmad 2006).

Although vibrating tillage tools reduce the draft requirements and allow a relatively smaller tractor to perform primary and secondary tillage tasks that would have otherwise required a large tractor, they introduce significant vibration issues leading to nonlinear systems (K. Sakai 2009). Figure 11 presents the work of tillage tools with flexible tines.

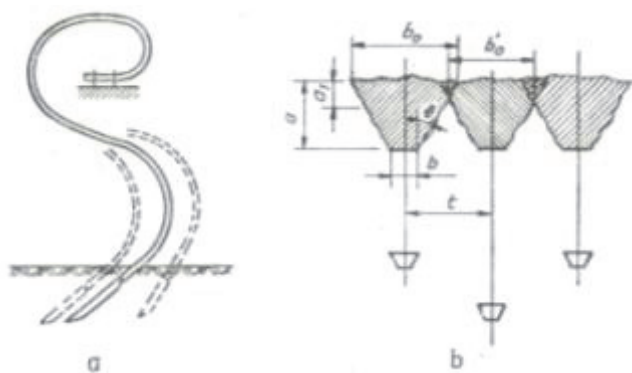


Fig. 11 The working process of the tillage tools.(St. Caproiu et al. 1982)

The Finite Element Method (FEM) is a powerful numerical technique that can be used to analyze complex engineering problems. It is particularly useful for problems that include geometric and/or material nonlinearities, as well as situations where underlying differential equations describing physical or biological phenomenon are nonlinear. Since most soil-machine/soil-plant interaction problems involve both material and geometric nonlinearities, FEM has been widely used to analyze soil/machine and soil/plant interaction problems [19]. Over the years several models have been made for solving FEM problems tillage, as follows: a nonlinear elasto-plastic Drucker-Prager 3D model (Araya, K., and R. Gao. 1995); a Duncan-Chang hyperbolic 3D model with tetrahedral constant strain elements for predicted soil failure and displacement pattern, draft and stress distribution of narrow blade at two rake angle (Chi, L., and R. L. Kushwaha 1990); a Drucker-Prager 2D plane strain model (Dechao, Z., and F. Qi. 1990); a Duncan-Chang with added strain rate term 2D plane strain model (Kushwaha, R. L., and J. Shen 1995); a 3D elasto-plastic model (Liu, Y., and Z. Hou 1985), a 3D cam clay critical-state model (Plouffe, C., et. al. 1999); a hypoelastic 3D model with strain rate effects (Rosa, U., and D. Wulfsohn, 1999); a dynamic elasto-plastic 3D model (Xie, X. M., and D. J. Zhang 1985); and a 2D plane strain model with interpolations on the stress-strains curve (Yong, R. N., and A. W. Hanna 1977).

The discrete element method (DEM) seems to be a promising approach for constructing a high-fidelity model to describe the soil–tillage interaction and may serve as a predictive simulation tool in the process of designing the tillage shape (I. Shmulevich 2010).

A discrete element model (Fig. 12) was developed to simulate aslurry injection tool (a sweep) and its interaction with soil using Particle Flow Code in Three Dimensions (PFC3D). In the model, spherical particles with bonds and viscous damping between particles were used to simulate agricultural soil aggregates and their cohesive behaviours (Chen Y. et. al. 2013).

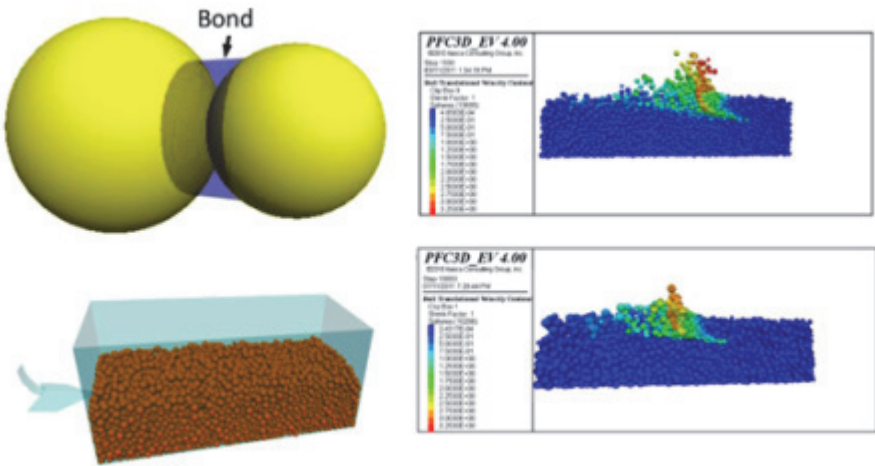


Fig. 12 The discrete element model developed using PFC3D: particles, box, and sweep. (Chen Y. et. al. 2013)

Another study presents the development of a three-dimensional (3D) discrete element method (DEM) model for the simulation of soil–sweep interaction (Tamas K., et. al. 2013). The aim was to understand the effects of the sweep rake angle and speed on draft and soil loosening (Fig. 13).

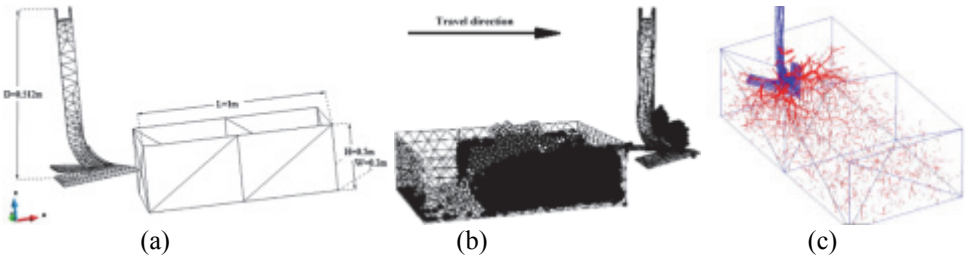


Fig. 13 Three-dimensional (3D) discrete element method model (a), Particle displacement and clod generation simulated with discrete element method (b), and simulation of crack propagation (c) (Tamas K., et. al. 2013)

The 3D CFD simulations were performed for a loam-clay soil (38% clay, 32% silt and 30% sand) (Fig.14), these conditions imposed the use of the finite volumes method (FVM) for the CFD simulation (I. Tenu et al. 2012).

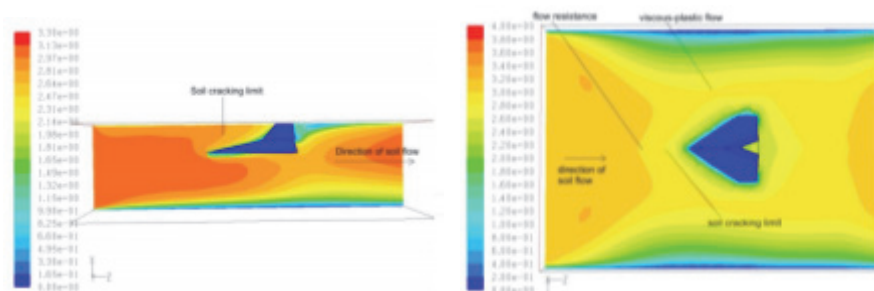


Fig. 14 Soil speed profile (m/s) in the longitudinal vertical plane and horizontal plane(I. Tenu et al. 2012)

CONCLUSIONS

1. The advantages of using vibro-combinators are: perfect preparation of seedbed in difficult working conditions and preservation of soil moisture. Such important factors can ensure fast, uniform and early germination of seeds, these requirements standing at the basis of abundant harvests.
2. Although vibrating tillage tools reduce the draft requirements and allow a relatively smaller tractor to perform primary and secondary tillage tasks that would have otherwise required a large tractor.
3. The discrete element method (DEM) and the finite element method (FEM) seem to be a promising approach for constructing a high-fidelity model to describe the soil–tillage interaction and may serve as a predictive simulation tool in the process of designing the tillage shape.

ACKNOWLEDGEMENTS

This work was supported by POSCCE based on 1CLT/800.024/21.05.2014 financing program.

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FEM ANALYSIS / TESTING RESISTANCE OF A TRACTOR SEAT

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ABSTRACT

Seats designed for equipping tractors and other means of transportation are usually tested under simulated testing and accelerated installations in order to determine the protection level which they can provide to those who sit on it for transport on public roads which usually travel with maximum speed (40 or 50 km / h, depending on the tractor). Normally these are not correctly sized after the performed optimization with specific programs, the seatback being too rigid or excessively elastic. The present paper presents a numerical model simulation for testing the resistance of a tractor seat that allows fast and precise of area determination subjected to high voltages, along with performed verification in real conditions by testing resistance under accelerated regime on a specialized stand, in order to determine if this ensures operator's safety.

Key words: Tractor seat resistance, FEM analysis, testing

INTRODUCTION

The importance of testing machines, equipment or components results from the fact that different types of tests, as part of the research, development, design, manufacture, service and repair of products contribute significantly to their continuous improvement, in all phases. Mechanical testing aim to:

- to check if the main constructive parameters, technical and economic indices, workmanship, performance, operational safety and wear resistance of components, subassembly or products comply with the technical documentation of the designing company;
- to undertake a continuous quality control of manufacture (repair), verification and improvement of prototypes or of new processes and materials etc., at the producing and repairing companies;
- in operation, to determine the type of component, subassembly or product most suitable for specific operating conditions, and to determine the best working regimes;
- to obtain comparative technical data for new design works or for manufacturing processes;
- to provide data for determining the service life of the component, subassembly or product.

After their destination, mechanical testing classify as: durability testing and testing for determining of various parameters. Durability testing can be:

- *long term testing*: are made to determine the length of service in real operating conditions, characterized by normal testing regimes, corresponding to the real operation;
- *simulated and accelerated testing*, characterized by overloading machines, equipment or components under forced regimes, operating at low periods under laboratory conditions or on special tracks that provide such regimes.

As testing of mechanical structures under accelerated and simulated regimes, although they are of relatively shorter duration than those achieved in operating conditions (about 10 times), are generally destructive - the structure is deformed and cannot be further used, even if not cracked / broken.

The finite element method is based on the principle of the overall potential energy, which states that a structure or a body is deformed or displaced in a position that minimizes the potential energy (overall potential). The principle of the minimum potential energy has many applications in the mechanics of the solid bodies and in the analysis of structures. In these cases, the principle of the minimum overall potential is a special case of the principle of virtual mechanical work applied to systems being under the action of conservative forces. The principle of the virtual mechanical work states that the virtual mechanical work of the exterior forces is equal and opposed to the virtual mechanical work of the interior forces (normal stress, shear stress, torsion and bending stress). It is assumed that forces and stresses remain constant and only the variations of strains are taken into account; only the strains that satisfy the internal compatibility of the body and the boundary conditions (resulting from the connections to other bodies) are accepted [8].

The finite elements method was imposed by the need to solve complex problems regarding the mechanics of deformable bodies. The method may be also applied to the problems referring to the flow of fluids, heat transfer, magnetic fields etc. [14]. Finite elements analysis (FEM) [2, 3, 10] of structures emerged as a necessity [1] to simplify and

reduce the cost of testing in operation or under simulated and accelerated regimes, it can approximate to within acceptable precision the areas of maximum stress (critical) [13], the maximum tensions and even the life of a structure.

In this purpose, many research were conducted on the use of FEM analysis for: the study of interaction between the driving wheel and rolling track for agricultural land vehicles [4], analysis of stress and strain distribution in an agricultural vehicle wheel [5], analysis of stress and strain distribution in various tractor components [6], the optimize of the wheel tires exploitation for agricultural vehicles, structural static analysis of lateral rods of the tractor linkage mechanism [7], fatigue behavior of various mechanical equipment [9, 11, 12], security and safety of the tractor, combine and agricultural machines, etc. [15, 16].

If we refer only to the operator's seat that is fitted to any farm tractor or self-propelled agricultural machinery, its testing is very important whether it is done by FEM simulation and testing under simulated and accelerated regime, as it is a critical safety feature when talking about operator safety and health.

MATERIAL AND METHODS

For numerical simulation in order to study the security the chair secures to the tractor operator's seat, the following assumptions have made:

- the drawings for these seats were developed in the "classical form", i.e. not in the form of CAD files.
- it was necessary the stage of geometric modelling, i.e. the transposition into CAD files of the classic execution files.
- the drawing of geometric patterns was made using Software SOLIDWORKS 2007 package. This "shortcoming" was actually a small advantage since geometric models have been developed so that unimportant details for the structure of resistance were eliminated at this stage.

Numerical simulation by finite element method was done taking into account the same stress conditions laid down in Regulation 80, by which has been highlighted the state of stress and strain. Finite element simulation was conducted on a geometric model of the operator's seat imported into the finite element analysis - ANSYS.

Meshing of the geometrical model was made in 186 Solid finite elements, using 269312 mesh elements and 69690 nodes (fig. 1 and 2).

Were established the boundary conditions imposed to the geometric model (fig 3), consisting of a fixed bearing applied to the retainer bracket of the seat to the floor of the tractor seat and two tensile forces applied to the points stipulated in Regulation 80 ECE ONU (which sets the conditions to test the seats).

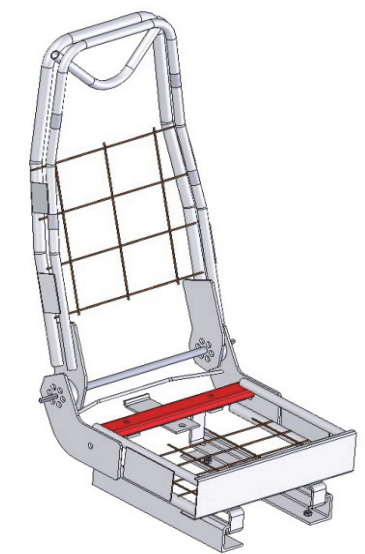


Fig. 1 Geometrical model of the resistance structure of operator's seat

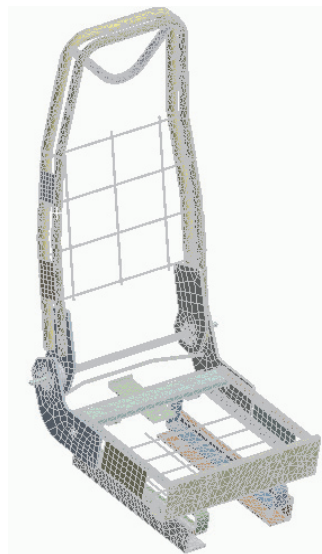


Fig. 2 Overview of the mesh used for the resistance structure of the operator's seat

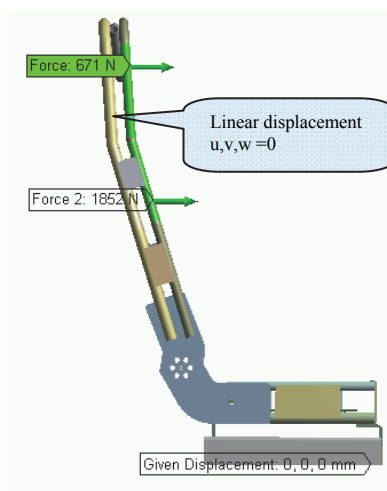
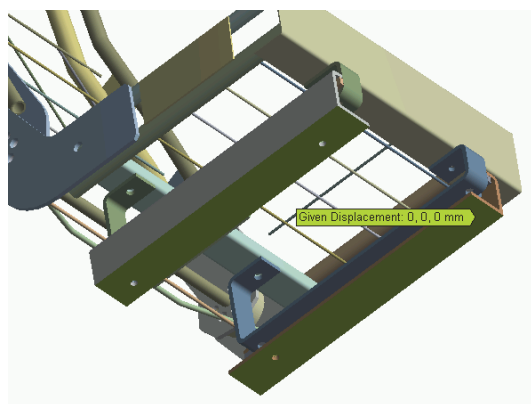


Fig. 3 Boundary conditions imposed to the geometric model

RESULTS AND DISCUSSIONS

Testing the resistance of operator's seat by simulating the stress state

The distribution of stress and strain for the *case of static stress* at maximum force of 84.5 kN (applied under the shown load conditions), is shown in figures 4, 5, 6 and 7.

Based on the developed calculation model was made an assessment of the state of stress and strain of the seat assembly, determining the total strain in the forces application points.

Equivalent stress distribution was used in the next step for assessing the resistance of tractor operator's seat.



Fig. 4 Von Mises equivalent stress

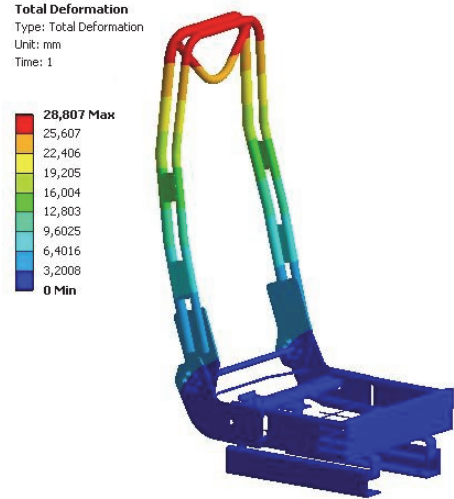


Fig.5 Total deformation

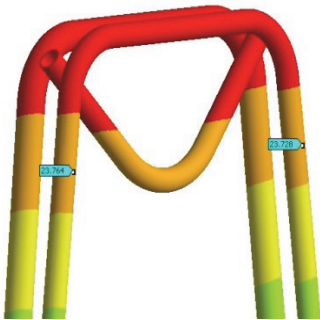


Fig. 6 Strain of upper points of force application

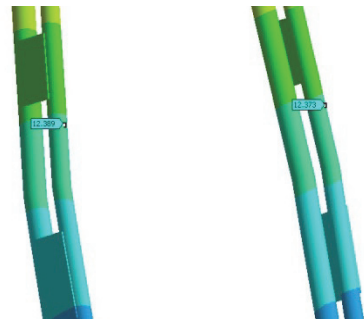


Fig. 7 Strain of lower points of force application

Resistance calculus for operator's seat

Resistance of pilot seat was expressed by determining the number of load cycles to failure, using the fatigue analysis module of ANSYS program.

Evaluation of the number of cycles to failure was based on Haigh diagram of limit cycles, by applying Soderberg schematization (fig. 8), and the fatigue curve of the material.

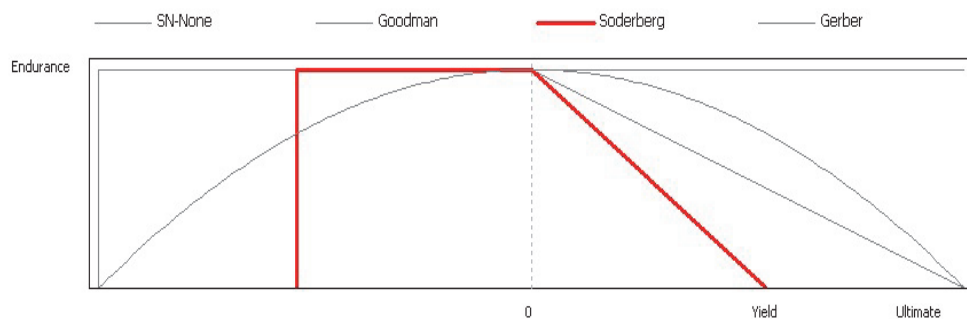


Fig. 8 Soderberg schematization

Resistance calculation was done for a number of $1e^6$ load cycles with constant amplitude and with asymmetry coefficient $R = 0.0053$ (fig. 9 and 10). $F_{\max} = 3704 \text{ N}$; $F_{\min} = 20 \text{ N}$



Fig. 9 Seat resistance

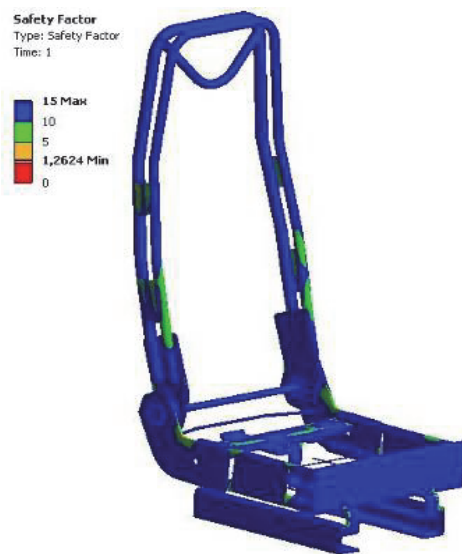


Fig. 10 Safety coefficient

Based on simulation performed under variable stress regime, fatigue behavior of the tractor seat was established.

Checking tractor's seat resistance by experimental tests

Experimental test was conducted at the National Institute of Research - Development for Machines and Installations Designed to Agriculture and Food Industry - INMA Bucharest, on a specialized testing stand (fig. 11).



Fig. 11 Equipment for testing under simulated and accelerated regime, type Hidropuls

Resistance test is performed in the tractor seat when installed on a specialized test stand (fig. 12, 13 and 14).

Fixing of the seats on the stand and preparing them for the test was done in accordance with Appendix 1 of Regulation 80, section 2.1.2, and 2.3.

Testing forces set were provided by means of 4 hydraulic cylinders of 25 KN.

Measurement of forces and deformations was made using measuring devices belonging to the stand, directly linked to the testing bodies to reduce measurement errors.



Fig. 12 Total view of seat testing stand within the equipment for testing under simulated and accelerated regime, type Hidropuls



Fig. 13 Detail images of seat securing and load application on the seat on stand

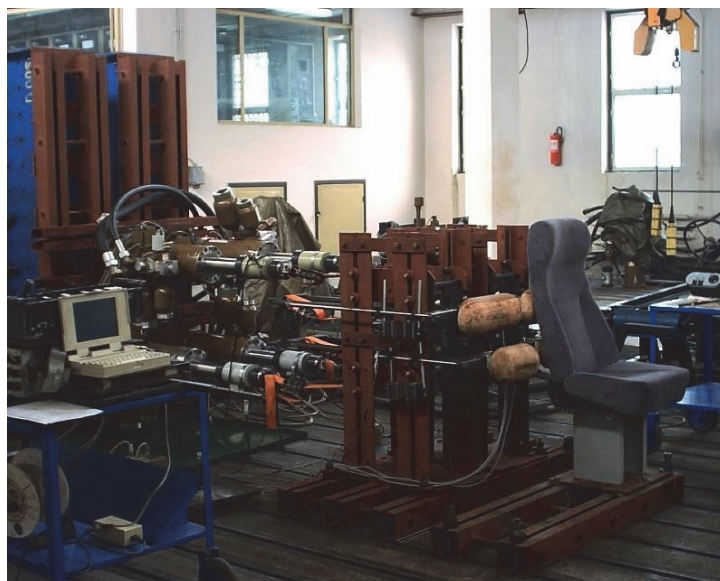


Fig. 14 Detail on seat securing and application load on the seat on stand, for rear shock

Testing parameters (according to Regulation 80) are shown in Table 1.

Table 1

No.	Name of parameter	Value	Observations
1	Height of the upper point of force application, H1	0.745 m	amendment 1, appendix 5, point 2.2.1.2
2	Value of applied force	1342 ± 50 N	according. amendment 1, appendix 5, point 2.2.1
3	Height of the lower point of force application, H2	0.54 m	amendment 1, appendix 5, point 2.2.2
4	Value of applied force	3704 ± 100N	according. amendment 1, appendix 5, point 2.2.2
5	Displacement of the upper point of force application	min. 100 mm max. 400 mm	amendment 1, appendix 5, point 1.2 and 1.3.1
6	Displacement of the lower point of force application	min. 50 mm	amendment 1, appendix 5, point 1.3.2
Parameters (temporal) of electrical signals for control of applied forces			
7	Time corresponding to forces increase (from min. 20 N to values specified in no. 2 and 4)	2.2 sec.	-
8	Time corresponding to maintaining of forces specified at no. 2 and 4 (landing control signal)	0.55 sec.	min. 0.2 sec. according to appendix 5, point 2.2.6
9	Time of forces decrease to the initial value	2.2 sec.	-

Actual values of the applied forces (horizontal forces, applied to the median plane of the seat, acting back forwards) and of the movements made by the action of these forces are shown in Table 2.

Table 2

No.	Name of parameter – Operator's seat –	Value
1.	The maximum force achieved during the period of applying the control electrical signal control (force), in the upper point of application	1370 N
2.	Maximum deformation resulting from the application of force during the test cycle, in the upper point	76.5 mm
	Residual deformation of the upper point	23.4 mm
3.	The maximum force achieved during the period of applying the electrical signal control (force), in the lower point of application	3730 N
4.	Maximum deformation resulting from the application of force during the test cycle, in the lower point	64.7 mm
	Residual deformation of the lower point	18 mm

By analysing the results obtained by simulation with finite element method (FEM) and by experiments in real conditions on the stand, the strains recorded at the point of application of force (table 3) were:

Table 3

Name of parameter	Value obtained from experiments [mm]	Value obtained from FEM simulation [mm]	Value specified by R 80 [mm]
Deformation in upper points of force application	23.4	23.7	37.2
Deformation in lower points of force application	18	12.3	

CONCLUSIONS

Following the results obtained by FEM simulation or by experimental testing on the stand, the following can be stated:

- after tests completion, there have not been found ruptures or separations of seat parts or of the platform;
- the correlation between the experimental results and those obtained by numerical simulation verifies the correctness of the development of calculation model with finite element analysis;
- the approach to the fatigue phenomenon allows an accurate assessment of the safety of a structure based on triaxial stress state, calculated in each point of the structure and also considering each individual application cycle;
- the results of fatigue calculation results indicate that during the application of $1e^6$ cycles, the structure – the seat, shows no risk of degradation;
- the cost of the simulation is much reduced compared to that of the experiment;
- the calculation model thus developed can be used effectively for the study of resistance for new constructive seat types.

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MODAL ANALYSIS USING FEM OF THREE ACTIVE ELEMENTS FOR AN AGRICULTURAL MACHINE

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ABSTRACT

This paper aims to determine the proper frequency, using finite elements method-MEF for three active structural elements that can be found in the component of an agricultural machinery used in agriculture for soil preparation for germination.

Numerical analysis carried out aim is to know the frequencies of each active element in part to be able to determine the work schedule and for what soil types can be used these working elements.

Numerical analysis was carried out on three types of active work elements, namely DELTA1, DELTA2 and GAMMA. For each element have been determined first three vibration modes.

In order to achieve geometric models has been used CAD program CATIA and for numerical models has been used ANSYS program.

Depending on the results obtained from the modal analysis may be determined working parameters of the agricultural machine - vibro-combinator, namely the power of tractor, forward speed, the soil processing depth.

For validating numerical models some experimental tests were carried out in order to determine the proper frequency.

The system used in experimental tests is a product of the company Brüel & Kjær namely PULSE-used in recording and analysis of vibration, used very well in diagnosis of vibration processes of machines and equipments. It is equipped with a specific software for processing and analysis of the measured

data. Analysis of FFT (Fast Fourier Transform) presents the following facilities: crosrange, Post processing functions, Hilbert transform, monitoring the input signal in the time domain.

Key words: FEM, agricultural machine, modal analysis, proper frequency.

INTRODUCTION

Modern agricultural operations now demand the utilization of a wide variety of equipment and specialist machinery systems, with many having rotary elements such as axles, gears, pulleys etc. With these agricultural machinery systems which have rotary elements, uncontrolled vibrations may become an important problem to consider. When the initial 'switch-on' frequency meets with the natural frequency of a machine element in the system, undesired noise, high levels of vibration and mechanical failures may occur during operation. In this regard, it is important to predict natural frequency modes of the elements under loading as a result of these vibrations [1].

Deep tillage tools are one of the primary components of agricultural equipment which experience high level soil reaction forces during tillage operations. These forces may cause plastic deformation or failure which is undesirable for tillage machines/tools. In particular, fasteners such as bolt connections, which are utilized in the fastening of structural elements to the tillage tool's framework, may become a key point for possible machine failure during tillage operations [2].

The active tillage elements of agricultural machineries require extensive studies in order to obtain a proper soil fragmentation and displacement. Determination of proper frequencies for these elements assists the designers in predicting the right speed for plowing.

METHODS

A series of finite element analyses and experimental tests were conducted, in order to establish the dynamical characteristics and proper frequencies of three active tillage elements of agricultural machineries for soil prepping and germination. The investigated structures are: DELTA 1, DELTA 2 and GAMMA tilling elements.

Performing the numerical modal analyses requires several steps: creating the geometrical model, proper finite element type selection, meshing the models and imposing the boundary conditions.

The geometrical models for the three active elements (as depicted in figure 1), were created using the SolidWorks CAD software [3].

Obtaining accurate numerical results requires a proper meshing procedure using an advanced form of a solid element. Thus, the Solid 186 finite element was selected from the Ansys solver library. The accuracy of this element comes from its parabolic form with median nodes. The geometrical shape of the Solid 186 is presented in figure 2.

An adaptive meshing procedure was imposed, with an element size of 1mm, obtaining 2.463.575 nodes and 818.080 elements for the DELTA 1 tillage, 3.065.163 nodes and

1.014.956 elements for the DELTA 2 tillage and 1.973.488 nodes and 775.871 elements for the GAMMA tillage. Detailed images of the mesh area are presented in figure 3.

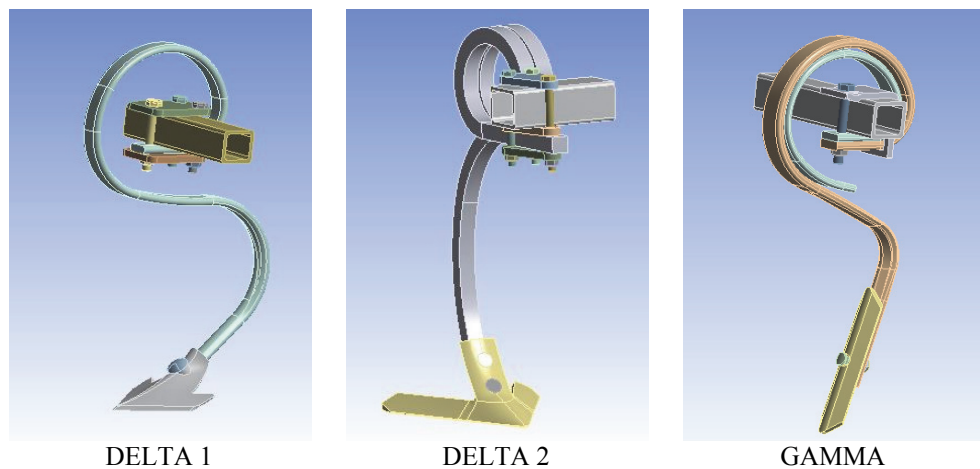


Fig. 1 Geometrical models for the three active elements

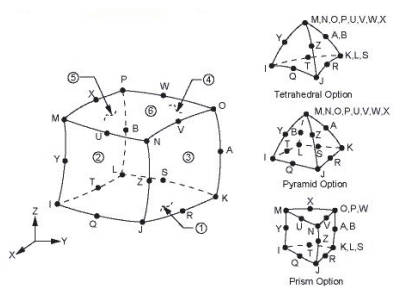


Fig. 2 Geometrical shape of Solid 186

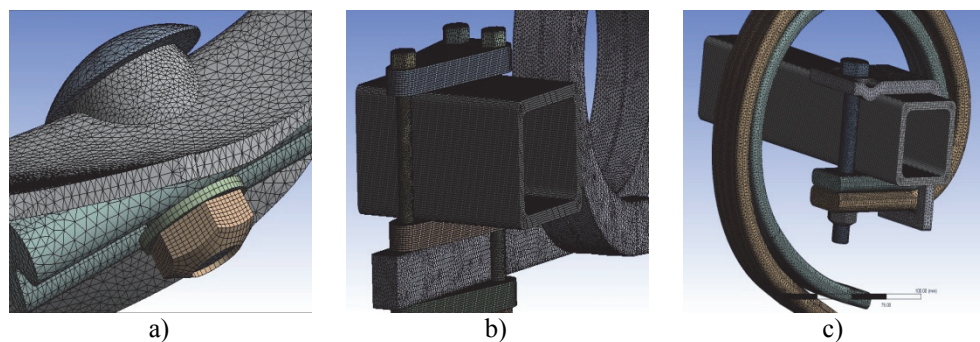


Fig. 3 Detailed area of the mesh for a) DELTA 1, b) DELTA 2 and c) GAMMA

The boundary conditions imposed for the models are depicted figure 4. The constraints were placed on the supporting beam as in the real life model

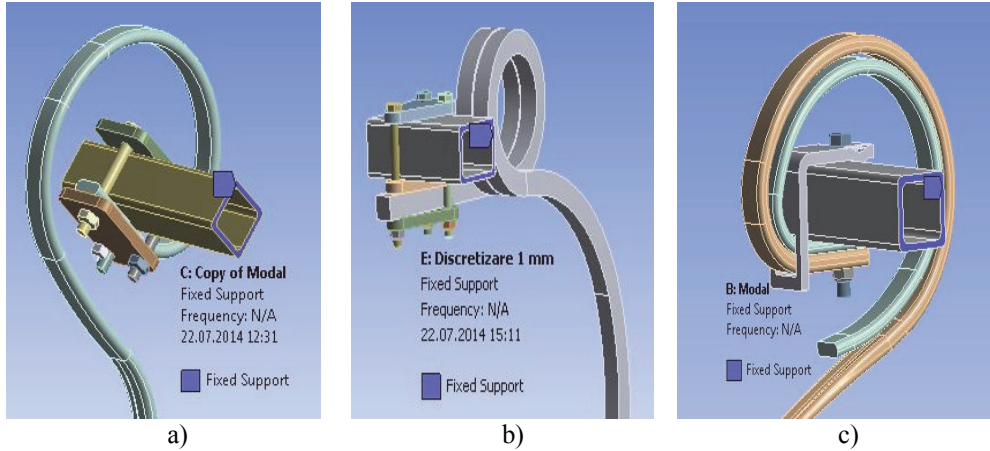


Fig. 4 Detailed boundary conditions for a) DELTA 1, b) DELTA 2 and c) GAMMA

The numerical analyses require validation for the method and results confirmation. Obtaining these, impose the need for experimental tests. Using the Brüel & Kjær PULSE system the DELTA 1 and DELTA 2 tillage element. Figure 5 shows the experimental setup and different channel configuration for DELTA 2. In total 12 tests were created.

The channel configuration setup (Fig. 5. b) and c)) for the first test were placed as follows:

- channel 1 (C1) registers the applied force on the chisel for all tests;
- channel 2 (C2) measures the frequency response on vertical direction at the end of the tillage;
- channel 3 (C3) measures the frequency response on longitudinal direction;
- channel 4 (C4) measures the frequency response on vertical direction for the fixing point of the tillage;
- channel 5 (C5) measures the frequency response on longitudinal direction for the fixing point of the tillage;

The channel configuration for the ninth (Fig. 5. d)) test presents differences form the first test only channels 2 and 3: channel 2 (C2) measures the frequency response on longitudinal direction for the end of the tillage and channel 3 (C3) measures the frequency response on transversal direction for the same point as C2.

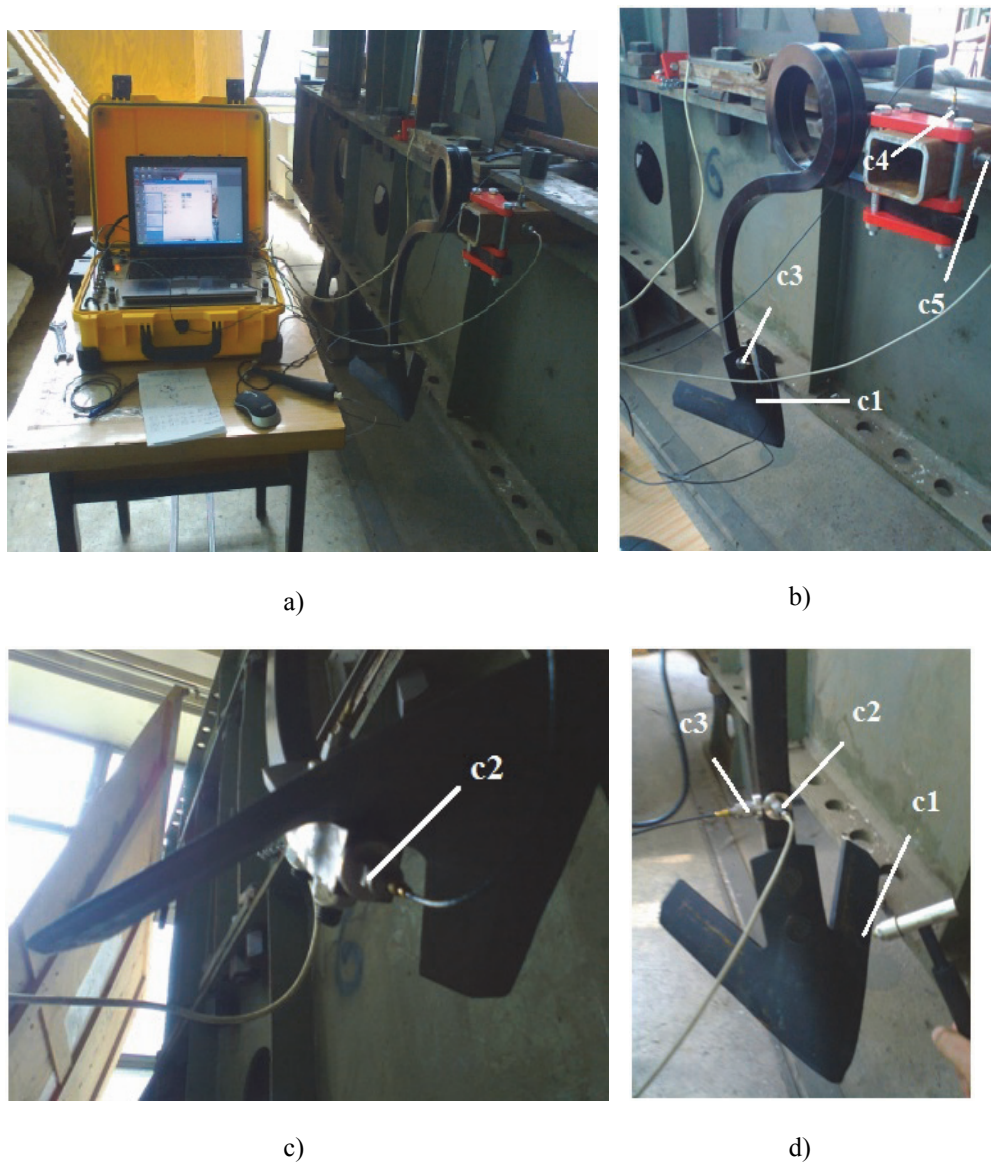


Fig. 5 Experimental setup(a)), channel configuration for the first test (b), c)) and channel configuration for the ninth test (d))

RESULTS AND DISCUSSION

The results obtained from the FEM analyses offer us the frequency response and proper frequencies for all the three models.

Thus, figure 6 offers the first six proper frequencies for the DELTA 1 tillage, figure 7 the same results for DELTA 2 tillage and figure 8 for the GAMMA tillage.

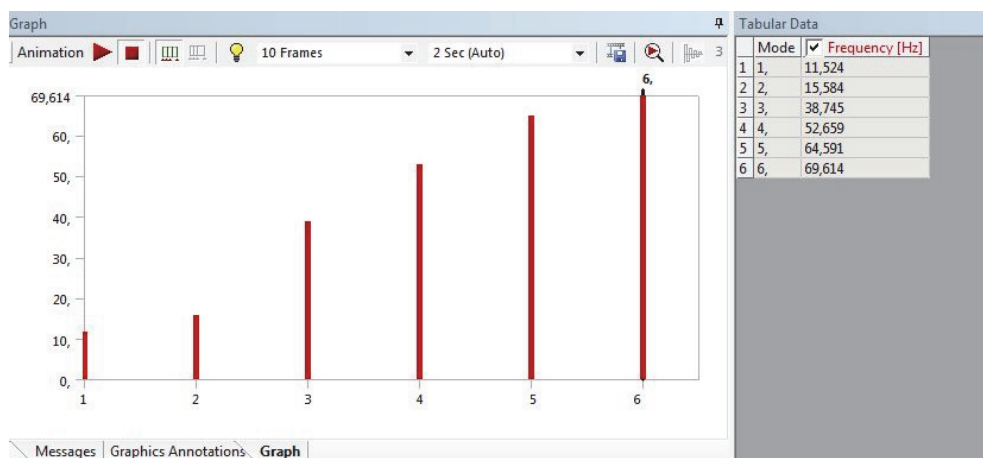


Fig. 6 The first six proper frequencies for DELTA 1

The first proper frequency for DELTA 1 was obtained at a value of 11.52 Hz on longitudinal direction, the second frequency was obtained at 15.28 Hz on transversal direction and the third on vertical direction with a value of 38.75 Hz.

For DELTA 2 the first proper frequency was obtained at a value of 12.47 Hz on transversal direction, the second frequency was obtained at 13.97 Hz on longitudinal direction and the third on vertical direction with a value of 55.85 Hz.

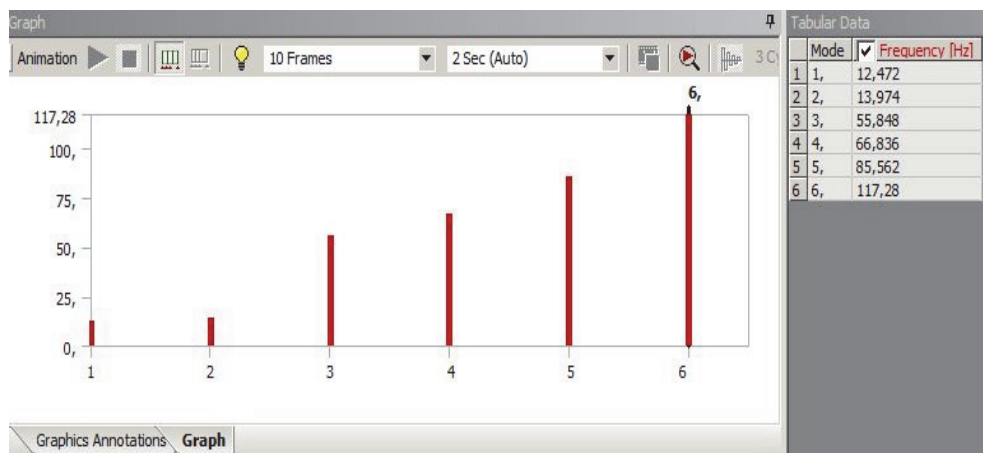


Fig. 7 The first six proper frequencies for DELTA 2



Fig. 8 The first six proper frequencies for GAMMA

Table 1 Experimental result for DELTA 1

Channel N°	Proper frequency N°							
	1		2		3		4	
	Freq [Hz]	Mobility [m/Ns]	Freq [Hz]	Mobility [m/Ns]	Freq [Hz]	Mobility [m/Ns]	Freq [Hz]	Mobility [m/Ns]
2	11,25	91,7	15,25	3,85	20,75	4,46	40,75	1960
3	11,25	23,2	15,25	43,1	19,75	0,288	40,75	297
4	11,25	3,3	-	-	-	-	40,75	535
5	11,25	11,9	-	-	20,75	2,07	40,75	1460

Table 2 Experimental result for DELTA 2

Channel N°	Proper frequency N°			
	1		2	
	Freq [Hz]	Mobility [m/Ns]	Freq [Hz]	Mobility [m/Ns]
2	14	15,4	63	9,18
3	15	12,8	63,75	3,64

The first proper frequency for GAMMA was obtained at a value of 15.48 Hz on longitudinal direction, the second frequency was obtained at 18.06 Hz on transversal direction and the third on vertical direction with a value of 50.76 Hz.

The experimental tests, were conducted only for the DELTA 1 and DELTA 2 working elements and offered the same results as in the finite element analyses. The obtained data are presented in table 1 for the DELTA 1 tillage and in table 2 for the DELTA 2 tillage.

CONCLUSIONS

The numerical model validation was achieved by comparing the FEM results with the experimental results. Table 3 highlights the differences between the numerical model results and the experimental results for the tillage elements.

Table 3 Numerical and experimental results for DELTA 3 (a)) and Calculated error between results for DELTA 1(b))

a)			b)	
DELTA 1				
Frequency [Hz]			Error DELTA 1	
	FEM	Experimental		
1 st Proper Freq.	11,52	11,25	1 st Proper Freq.	2,40 [%]
2 st Proper Freq.	15,58	15,25	2 st Proper Freq.	2,16 [%]
3 st Proper Freq.	38,75	30,5	3 st Proper Freq.	27,05 [%]

Taking into consideration the required speed of the agricultural machinery during working periods (preparing the soil for germination), only the first proper frequency can be taken into account, the latter frequencies being impossible to achieve with the regarded working speeds.

Considering the results and the calculated errors, one can say that the finite element modeling for these tilling elements can be used with no restrictions or limitations regarding the accuracy of the results. A 2.4% error cannot be taken into consideration as problematic.

These results give us a starting point in designing a new agricultural machine with modular working elements, without the need of initial field testing.

ACKNOWLEDGEMENTS

This work was supported by SOP IEC program based on 1CLT/800.024/21.05.2014 financing contract.

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A METHOD OF CALCULATING THE OPTIMAL SPEED OF OPERATION FOR VIBRO-CULTIVATORS

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SUMMARY

This paper presents a method of calculating the optimal speed of operation of the tractor – vibro-cultivator unit [5, 6, 7, 8, 9, 10, 11, and 12]. The principle of calculation is based on the choose of the unit speed of operation depending on direction of movement on a soil so that the periodic excitation caused by the working tool - soil contact (plowing furrows) can achieve a frequency as close to the natural frequency of the elastic suspension of the vibro-cultivator. It produces resonance and thus increasing the amplitude of vibration of the working tool. This involves reducing friction and a better processing of soil by soil break up caused by the energy discharge of the elastic deformation for the tool suspension.

Key words: vibro-cultivator, optimization, operation speed, modal analysis.

INTRODUCTION

The paper presents a study on the optimization of working regime of vibro-cultivators based on speed and direction of their movement. Study presents a method of calculating the optimal working speeds of aggregates consisting of tractor and vibro-cultivators.

Vibro-cultivators are machines for seedbed preparation. They are equipped with tools sustained by elastic suspension. The elasticity of supports facilitates the oscillations of working tool – elastic support assembly. This set has a natural mode shapes which corresponds to a natural frequency of vibration.

According to the classical theory of linear viscoelastic oscillator or even the dry friction, the oscillation amplitude will be at maximum at the proximity of natural frequency of excitation of the assembly.

The assembly will oscillate on frequency forced oscillation caused by contact between tool and profiled soil

The soil on working vibro-cultivators is profiled (working hypothesis) As a result the working body is loaded unevenly, even if regular working speed is constant. Intensity load (contact force) depends on soil and the working tool quality. If working speed is constant, the excitation frequency depends on the width of plowing, the speed and the angle between the direction of movement and the furrow plowing land on which the tractor-vibro-cultivator unit operates.

The working tool – elastic support assembly behaves as an oscillator in a viscous medium and dry friction in the forced oscillation mode (anyway the vibrations reduce traction force, [3])

The calculation is based on the choice of working speeds of the unit on a fixed direction to the direction of furrows, so that periodic excitation caused by working body contact with soil (profile due furrows), to achieve a frequency as close to natural frequency of working body – elastic support assembly.

In this case the resonance will appear and the amplitude of vibration of the working bodies will be increase this involves reducing friction and a better processing of soil by grinding additional elastic energy caused by the discharge of body work.

This paper will deduce the formula for calculating the speed of work that produces optimal resonance and lead to high amplitude oscillations. This leads to decrease the friction between the soil and the work tool and a better soil crushing. These effects are the objectives of optimizing the working regime.

For the studied organs we determined theoretically and experimentally verified their lower two frequencies, one of which is along the movement direction, and the other one perpendicular on it. The order depends on the working body.

The problems of design, construction and operation of the vibro-cultivators have become a common concern in recent years, [1, 2, 3, and 14]. They are also more advanced solutions based on waves, [4, and 15].

MATERIAL AND METHODS

If the vibro-cultivator is working on tilled soil, with the moldboard width noted with b , then the tool - soil interaction gets a periodic component, as we can see from a simple calculation. We consider an unit moving on a tilled land with the moldboard width b , with the angle α between the movement direction and the furrows direction (fig.1).

The distance between two furrows on the movement *direction* (average) is:

$$d = \frac{b}{\sin \alpha} \quad (1)$$

Taking in account the figure 1 and the units speed v we obtain the excitation frequency of the oscillator working body – support assembly, given by the formula:

$$\varphi = \frac{v}{b} \sin \alpha \quad (2)$$

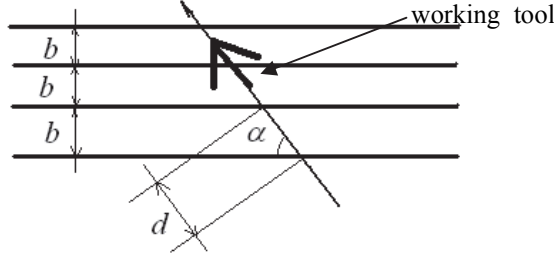


Fig. 1 The geometry workflow diagram of the vibro-cultivator – tractor unit

If:

$$\varphi_1 < \varphi_2, \quad (3)$$

are the lowest two natural frequencies of the working tool – support assembly, then to produce the approximate resonance phenomena (deterministic excitation must have a frequency as close as possible to the two own frequencies of the assembly), the following condition should be realized:

$$\varphi_1 \leq \varphi \leq \varphi_2 \quad (4)$$

By entering the expression (2) of the excitation frequency in expression (4), we obtain:

$$\frac{\varphi_1 b}{\sin \alpha} \leq v \leq \frac{\varphi_2 b}{\sin \alpha} \quad (5)$$

Formula (5) establish the range of the movement speed. It depends on the width of the working organ used for plowing, on the angle between the movement direction and the furrows direction, and on the first two natural frequencies of the working body – support assembly or only the support (the natural frequencies of assembly and support are very close).

If we want to gain maximum amplitude of vibration for the working bodies, then for any angle between the unit's movement direction and the furrows direction, the working speed must be chosen between the minimum and maximum speed curve defined in the following formulae:

$$v_{\min}(b, \alpha) = \frac{\varphi_1 b}{\sin \alpha}, \quad v_{\max}(b, \alpha) = \frac{\varphi_2 b}{\sin \alpha}. \quad (6)$$

RESULTS

In addition to angle between the units movement direction and the furrow direction, furrow width and the working speed, to calculate the optimal working speeds, the natural frequencies (along the movement direction and perpendicular thereon) are a great importance.

One-dimensional structural model for modal analysis

The one-dimensional structural model (with finite elements type BEAM3D) for each of the three working tools (named delta1, delta2 and gamma) analyzed is shown in table 2. The model includes the geometry, the restrictions (boundary conditions) and the loading forces given by the contact between the soil and the working tools. Arrows on the straight top model signify the restriction fixing to the chassis or the resistance frame. The material is linear elastic, a steel with $E = 210000$ MPa and the Poisson coefficient of 0.28, weight density of 7850 kg/m^3 . Finite elements 1D are type BEAM3D with 3 nodes, from the finite elements library of the COSMOS/M 2.8 software [16]. The geometrical characteristics of the working body support cross sections are given in the table 1.

Table 1 The geometrical characteristics of the working body support cross sections

	Tool	Area, mm^2	I_x , mm^4	I_y , mm^4	Depth, mm	Width, mm
Delta 1 	Superior section	353.10	3897.88	26087.61	12.00	3.20
	Inferior section	311.44	5142.82	15654.58	11.72	2.70
Delta 2 		625.00	32552.08	32552.08	25.00	25.00
Gama 	Superior section	370.27	4242.21	29626.03	12.00	32.00
	Inferior section	412.9	10490.02	23716.87	21.03	30.63

Modal analysis

The natural frequencies for each structure analyzed are shown in table 2, in Hz. These frequencies are used to determine the optimal work speeds based on the furrow width.

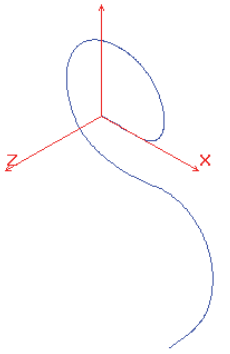
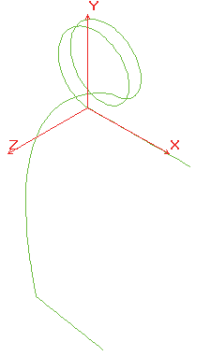
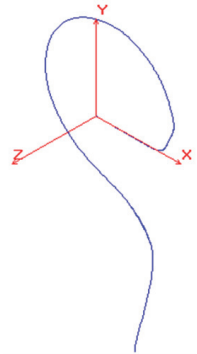
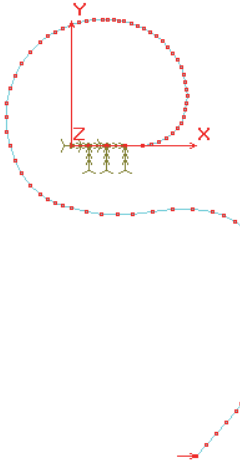
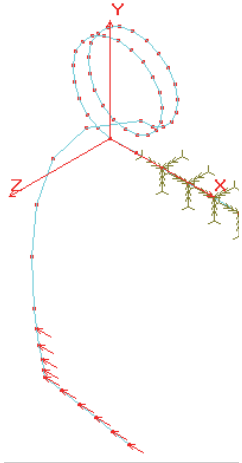
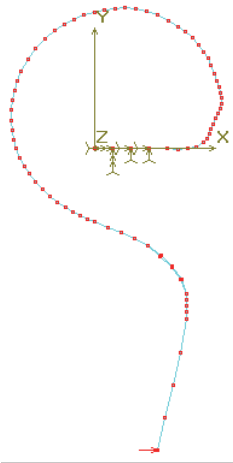
Results interpretation

The main results obtained in the modal and static linear elastic analysis for the working bodies, are given in table 2.

The obtain results have shown that the estimated natural frequencies are in accordance with the experimental results obtained by the other research team in the same project. There

is also a good accordance with the calculation of three-dimensional models made by other team in the same project.

Table 2 The results of the one-dimensional structural analysis for the working body support

Category	Working body delta1	Working body delta2	Working body gamma
Geometry			
Mass, kg	3.053	9.092	2.719
Their own frequencies, Hz	18.11	15.01	23.99
	26.85	15.90	40.27
	59.46	69.72	63.57
	79.99	67.37	104.99
	110.76	101.46	138.14
Structural model			

DISCUSSION

Optimum working speed is selected in optimal working range:

$$[v_{\min}(b, \alpha), v_{\max}(b, \alpha)]. \quad (7)$$

Speed range (7) is determined by the minimum and the maximum speed, both depending on the working width for each working body of the plow that has worked the soil and on the angle between direction of movement and furrow direction. The range (7) can be reduced to a single point in case of the first two natural frequencies of the working bodies are identical.

The length of this interval depends linearly on the difference between the first two frequencies of the body's support natural spectrum:

$$\Delta v = \frac{b}{\sin \alpha} (\varphi_1 - \varphi_2). \quad (8)$$

It is noticed that the length of the optimal speed range is directly proportional to the width of the working body of the plow used to tillage (average distance between two consecutive furrows) and the difference between the first two natural frequencies of the working body support and inversely proportional to the sine of the angle between the working direction and the furrow direction. For speeds calculated by formula (6), to be mathematical correct it is necessary for the angle α to be strictly positive. Obviously, values over 90 degrees are not of interests.

Case Studies

The working bodies supports whose structural models are given in table 2 are mounted on the frame of vibro-cultivator. The results of calculation for determination of the theoretical optimal speed range may be represented graphically for the minimum and maximum speeds depending on the angle between the movement direction and the furrow direction. These graphical representations are shown in fig 2, 4 and 6.

In the case for the support of the working body delta 1, for a working width of 25 cm and the perpendicular displacement on the furrows ($\alpha=90$ degree), the optimum theoretical speeds interval is [16.299; 24.165] in km/h, with an average value of 20.232 km/h. The interval is represented in fig. 2 by a vertical bold line.

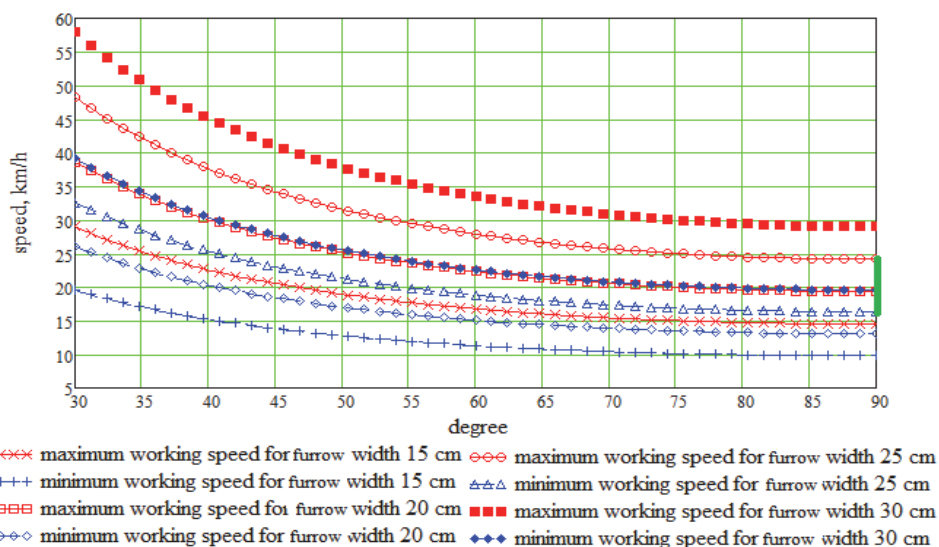


Fig. 2 The variation of the minimum and maximum speeds for the four theoretical cases of the working width b , reported to the angle α for the support of the working body delta 1 (see table 2)

The tractor speed in the real working conditions is between 5 and 18 km/h. The optimization of vibro-cultivators working regime will be evaluated up to 20 km/h maximum (fig.3).

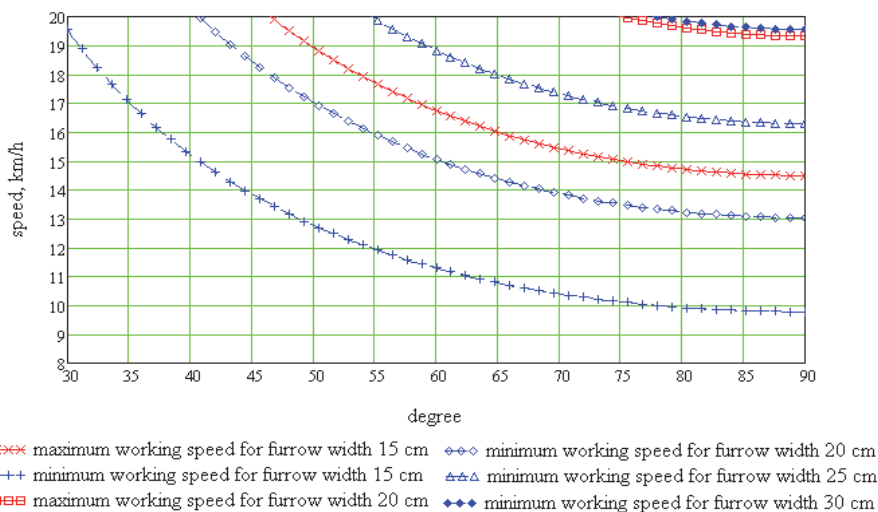


Fig. 3 The variation of the minimum and maximum speeds in the real working condition for the four cases of the working width b , reported to the angle α for delta 1

The maximum speed for furrow width of 25 cm and of 30 cm is limited at 20 km/h and it is not reached.

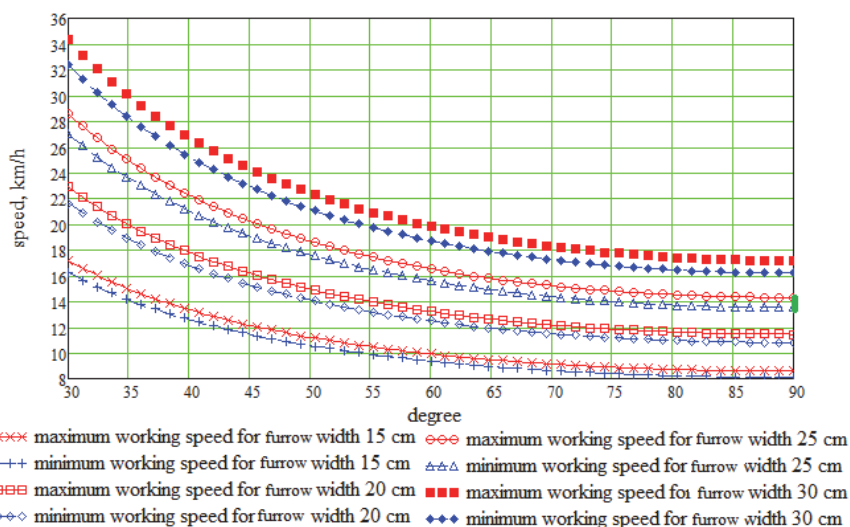


Fig. 4 The variation of the minimum and maximum speeds for the four theoretical cases of the working width b , reported to the angle α for the support of the working body delta 2 (see table 2)

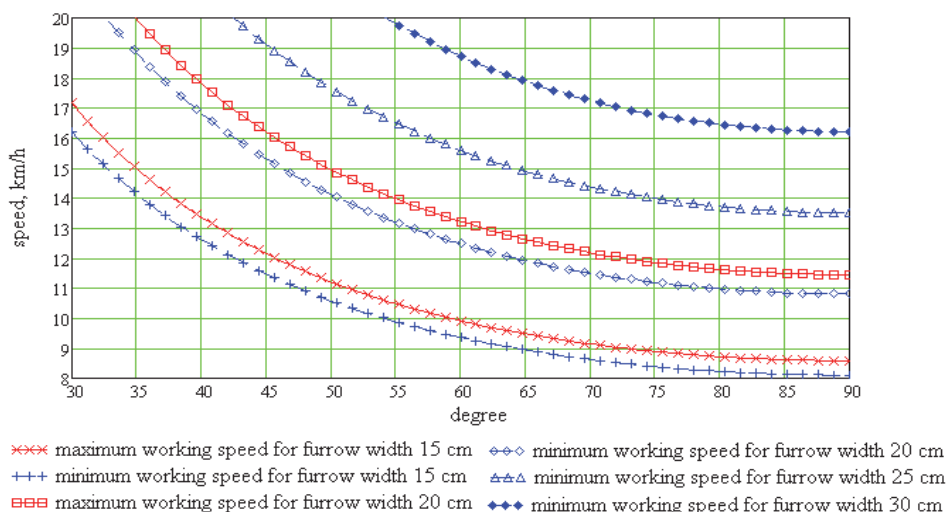


Fig. 5 The variation of the minimum and maximum speeds in the real working condition for the four cases of the working width b , reported to the angle α for the support of the working body delta 2

In this case for the support of the working body delta 2, for a working width of 25 cm and the perpendicular displacement on the furrows ($\alpha=90$ degree), the optimum speeds interval is [13.509; 14.310] in km/h, with an average value of 13.909 km/h. The interval is represented in fig. 3, by a vertical green bold line.

The graph for real conditions for delta 2 (maximum speed at 20 km) is presented in fig. 5.

In the real working condition for working body delta 2, the maximum speed for furrow width of 25 cm and of 30 cm is limited at 20 km/h and it is not reached.

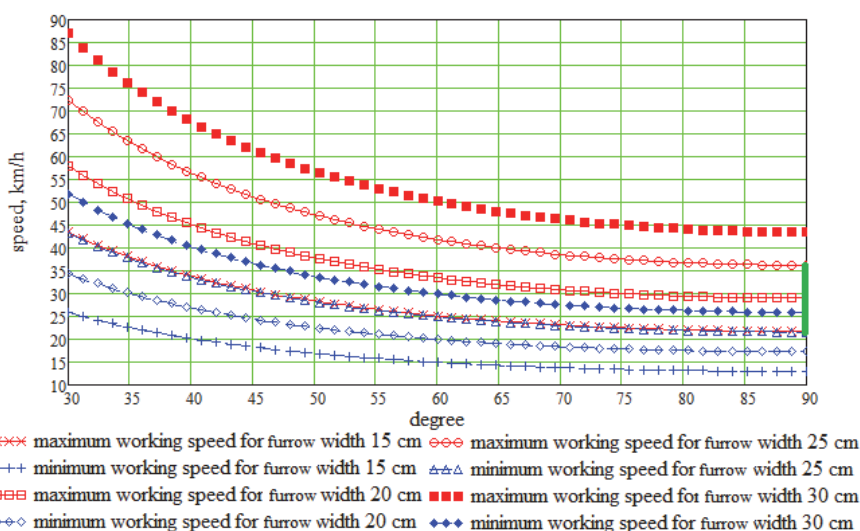


Fig. 6 The variation of the minimum and maximum speeds for the four theoretical cases of the working width b , reported to the angle α for the support of gama (see table 2)

In this case for the support of the working body gama, for a working width of 25 cm and the perpendicular displacement on the furrows ($\alpha=90$ degree), the optimum theoretical speeds interval is [21.591; 36.243] in km/h, with an average value of 28.917 km/h. The interval is represented in fig. 6. by a vertical bold line.

The graph for real conditions for working body delta 2 (maximum real speed at 20 km) is presented in fig. 5.

In the real working condition for the working body gama, the minimum speed for furrow width of 25 cm and of 30 cm is limited at 20 km/h and it is not reached. Also the maximum speed for all furrow widths (15 cm, 20 cm, 25 cm and 30 cm) is limited at 20 km/h and it is not reached.

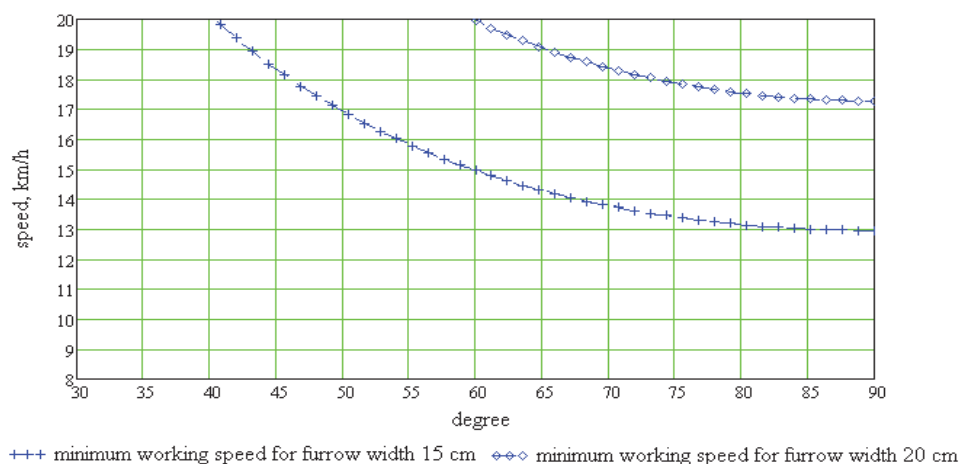


Fig. 7 The variation of the minimum and maximum speeds for the real cases of the working width b , reported to the angle α for the support of the working body gamma (see table 2)

CONCLUSIONS

Using (1) - (6) formulae and the results of the case studies we can establish few conclusions with the application for determination of the optimal operating modes of tractor – vibro-cultivator unit.

The first conclusion is that vibro-cultivators can achieve maximum performance in operation, if the working surface was profiled in advance and the work regime (movement speed and angle between the movement direction and the furrow direction) together generate vibrations in the working bodies as close to the their first two natural frequencies .

The optimum working regime at minimum speed is done for the perpendicular direction to the furrows. This regime will be selected when the tractor power is relatively small, with lower working capacity.

If availability of tractor power is high compared to that required, choosing a higher working speed to increase work capacity (with price growth and energy consumption) involves choosing a strictly positive angle between the movement direction and the furrow direction but also with values less than 90 degrees.

Choice the position of the working speed between the minimum and maximum value, is a matter of vibration to be studied separately to give an answer to possible increase amplitude of vibration in a direction depending on the beneficiary's working interests. A problem of this type are studied in [14], for example, a dedicated machine vibration tillage.

ACKNOWLEDGMENTS

This work was supported by SOPIEC programme based on 1CLT/800.024/21.05.2014 financing contract.

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THE ENERGY PARAMETERS OF THE TRACTOR-CHISEL PLOUGH

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SUMMARY

Contemporary agricultural production has high demands in sense of high productivity technical and production systems and thus imposes construction of new highly sophisticated technical solutions. One of these new solutions for the energy and economy efficient agricultural production is CASE STEIGER 400 tractor. The aim of the research was to determine the overall tractor working parameters and their optimization in tillage using a chisel plough. Obtained results show that the average fuel consumption during the field experiments was 38.8 l/ha, productivity 2.4 ha/h and energy consumption 68.6 kWh/ha. In the case of non-conventional tillage overall energy consumption was 250 MJ/ha, indicating that energy savings are feasible if adequate production technology is applied and technical systems used.

Key words: tractor, energy, working parameters, rationalization

INTRODUCTION

Soil tillage is an integral part of the complex production processes that are influenced by numerous economical and ecology demands. These demands are changeable depending on the agricultural production conditions. Regardless the soil and water protection, ecological production with the reduction of production costs, the key of success in sustainable agricultural production is optimal choice of the tractor-machinery aggregates for the tillage (Arvidsson *et al*, 2004).

The most important tasks for tillage are to provide optimal structure of the seed layer with the adequate air, water, nutrient and temperature regime (Đević, 1992).

Reduced tillage is very interesting solution in sense of energy and cost saving as well as in the sense of the optimal working regime of the tractor-machinery aggregates. The applied tillage technique should minimize the energy inputs in crop production (Tabatabaee *et al*, 2004).

et al, 2009). Reduced tillage application is limited by production technology and in that sense it is applicable in crop production where there is no need for at crops with shallow sowing depth (wheat, sunflower, barley...). When applying the reduced tillage, care must be taken into account since after a few years' problems with the soil compaction and losing of the good properties of arable layer occur. However, the fact that with the reduced tillage, energy input could be 2 up to 3 times lower, can not be neglected (*Mileusnić et al*, 2010).

In this paper the energy consumption and tractor optimal working regime in tillage with chisel plough was determined with the aim of analyzing if and how the production technology influences on the system energy efficiency.

MATERIAL AND METHODS

For all experiments a four-wheel drive tractor CASE STEIGER 400 with a 12.9 L 6/WGT engine was used. Due to to the 40 % reserves of torque, the tractor is able to meet all the requirements expected in the worst working conditions. According to Nebraska OECD test 2046 (CODE II) report, maximum power measured at the PTO shaft is 291.7 kW at 1998 rpm with specific fuel consumption of 236 g/kWh (ECE-R120). Maximum engine torque is 1899 Nm at engine regime of 1400 rpm. Transmission gear is 16/2 Power-shift PS4. Linkage mechanism is a Category IV-N with lifting force of 9740 daN. The total fuel energy intensity rate (MJ/ha) is calculated by multiplying the fuel consumption (kg/ha) by 44 MJ/kg (*Nikolić and Budinčević* 2000)

In accordance with the objectives set, the subject of research is 4x4Z CASE STEIGER 400 tractor in the aggregate with chisel plough Great Plains TCN 53.1. This paper presents the following indicators:

- drawbar force (measured by HBM U2b transducer and the acquisition of MX 840)
- velocity (measured travelling on a known distance)
- slip of wheels calculated according to equation:

$$\delta = v_t - v_s / v_t \quad (1)$$

- efficiency coefficient of tractor calculated according to equation:

$$\eta_t = P_v / P_m \quad (2)$$

- fuel consumption per area unit (was obtained by volumetric method)
- fuel consumption per area unit calculated according to equation:

$$Q_{ha} = Q / W \quad (3)$$

- work rate calculated as in equation:

$$W = 0.1 b v \quad (4)$$

Table. 1 Technical characteristics of tested machinery

<i>Technical characteristics of tractor</i>		<i>Technical characteristics of chisel</i>	
CASE STEIGER 400		Great Plains TCN 53.1	
Engine power ECE R120 [kW]	292	No of working elements [-]	12
Rotation rate at max power [min ⁻¹]	1998	Machine width [m]	3.0
M _{max} /n _{Mmax} [Nm/ min ⁻¹]	1899/1400	Working width [m]	4.2
q [g/kWh]	236	Tillage depth [cm]	to 31
Energy/design-mass ratio [kW/t]	17.98	Type of machine[-]	pulled
Specific mass without ballast [kg/kW]	55.61	Weight [kg]	4756
Specific mass with max. ballast [kg/kW]	76.37	-	-
Weight without ballast with ballast [kg]	16350 22453	-	-

List of symbols:

Eha – spec. energy requirement [kWh/ha]	q – specific fuel consumption [g/kWh]
Fv - drawbar pulling force [kN]	Qha – fuel consum. per area unit [l/ha]
k _i – specific soil resistance. [N/cm ²]	v – velocity [km/h]
M _{max} – max. torque [Nm]	Wh – productivity [ha/h]
n _{Mmax} – speed of engine at M _{max} [min ⁻¹]	φ - adhesion [-]
Pv – drawbar power [kW]	δ - slip of wheels [%]
Pm - engine power [kW]	η _T – efficiency coefficient [-]
Q – hourly fuel consumption [l/h]	B - working width [m]

Working conditions

The experiment was carried out on 5.07.2013., »Široka bara« 22/2 location, on the farm “Vrbovsko” Agricultural Corporation, Belgrade („PKB“, in Serbia). The predominant soil type in the specified location is eutric cambisols with an average bulk density 1.194 g/cm³ and an average moisture content during the tests of 19.53 % at a profile depth of 25 cm (table 2). Bulk density was measured using the soil cylinders *Kopecký*, and soil moisture at a depth of arable layer is determined using the by *Kaczynski* 's method (see *Kaczynski 1958*).

Table. 2 Soil moisture and soil bulk density at 25 cm soil depth

No.	Sampling weight [g]	% moisture	Bulk density of soil [g/cm ³]
1.	114.44	23.48	1.144
2.	119.55	18.62	1.195
3.	89.75	15.16	-
4.	109.55	20.54	1.095
5.	134.3	19.89	1.343
Average	-	19.53	1.194

RESULTS AND DISCUSSION

Potential pulling characteristics of this tractor on stubble and ploughed soil, with the measured mass of 18.5 t, are presented in table 3. The optimal exploitation characteristics are obtained using the coefficients given by Obradovic (1990), and Renius (1999).

Table. 3 The optimal exploitation range of tractor in stubble and ploughed soil

No.	Brand and type tractors	The stubble						Ploughed soil	
		Fv [kN]			v [km/h]			Optimum	
		min.	opt.	max.	max.	opt.	min.	Fv [kN]	v [km/h]
1	2	3	4	5	6	7	8	9	10
1.	Case Steiger 400	50.80	81.70	90.70	14.00	8.70	7.80	61.70	7.50

On stubble tractor, can achieve maximum efficiency coefficient of 0.67 and at the same maximum power of 197 kW with a drawbar pulling force of 81.70 kN and the speed of 8.7 km/h, with the coefficient of adhesion 0.45.

Tractor energy parameters in the production

The results obtained during the testing are presented in tables 4 and 5.

Average fuel consumption of the tractor was 31.8 l/ha, its work rate 2.40 ha/h, while the energy consumption was 68.60 kWh/ha (Tab. 4). In the given soil condition, with the average load, tractor working regime was in the optimal zone. This can be seen when data from table 3 and table 4 are compared. Further analysis show that the velocity is lower compared to the presumed values and so is the tractor efficiency coefficient. Its value is 10% lower compared to the lower value of the exploitation range. The reason for obtaining such result is high resistance oscillation caused by the current poor soil state at the location. These oscillations went up to 110 kN. Working regimes for the rows 5 and 6 in table 4, show that the drawbar pulling force is out of the optimal exploitation range (see Table 3).

The same situation was observed for the slip of wheels, but it can be said that these values are in the tolerant range.

Table. 4 Tractor's working data on stubble

No	Pv[kW]	Fv[kN]	v[km/h]	δ [%]	Q[l/h]	Q _{ha} [l/ha]	W _h [ha/h]	E _{ha} [kWh/ha]
1.	143.00	66	7.8	8	75.00	28.60	2.62	54.60
2.	146.00	72	7.3	12	74.30	30.30	2.45	59.60
3.	169.60	86	7.1	15	75.00	31.50	2.38	71.30
4.	173.10	89	7.0	15	76.20	32.50	2.35	73.60
5.	176.30	92	6.9	18	77.00	33.20	2.31	76.30
6.	176.80	95	6.7	20	80.00	35.50	2.24	78.90
av.	164.10	83.30	7.1	14.70	76.25	31.80	2.40	68.60

Table 5 Energy consumption and the fuel efficiency for the tractor and chisel plough

Q _{ha} [l/ha]	Energy intensity rate [MJ/ha]	Total fuel energy E _{ha} [MJ/ha]	Fuel efficiency [%]
28.60	196.56	1054.54	18.64
30.30	214.56	1117.22	19.20
31.50	256.68	1161.47	22.10
32.50	264.96	1198.34	22.11
33.20	274.68	1224.15	22.43
35.50	284.04	1297.90	21.88
31.80	246.96	1172.53	21.05

Conventional tillage in the case of the mentioned PKB cooperation in Belgrade (Serbia) in crop production is high energy demanding. The average energy input varies from 268 MJ/ha to 298 MJ/ha (*Mileusić et al, 2010*) depending on tractor-implement aggregate type. In the intensive agriculture, using the tractor CASE STEIGER 400 and chisel plough, energy saving of 8 to 18% is possible, for the tillage depth of 25 cm. In the case of wheat that is sown in a shallow layer, energy savings could be more than 18% when compared to the conventional tillage. In the literature (*Cavalaris and Gemtos, 2004*) it is said that when tillage depth is higher than 30 cm then conventional tillage must be applied. If in such condition chisel plough is used, optimal conditions for the plant roots development as well as for the plant itself can not be achieved. Further more, if the sowing depth is not adequate this will directly reduce the yield and thus the profit in the production conditions of the “PKB” Corporation. Fuel energy efficiency in the tillage was 21% which is at the level of the conventional tillage (Tab. 5). Having in mind the fact that tractor is not working at the level of maximum efficiency coefficient (the coefficient is 10% lower) and that the fuel

efficiency coefficient is good, it can be concluded that the engine is very economical for the given working conditions.

Average working depth was 19.0 cm at soil moisture was 20%. Maximal achieved working depth was 25 cm and with the depth increase the fuel consumption increase was also observed (Fig. 1).

Fuel consumption per area can be adequately defined with the linear or square function since the regression coefficient is almost identical and for the linear model it is $R^2=0.9754$ and for the square model its value is $R^2=0.9758$. Linear model suggests that the depth increase of 1 cm increases fuel consumption per surface area for 1.263 l. Going from 15 cm to 25 cm of working depth fuel consumption increases 25%. In this condition slip of wheels increased from 6 to 20%. These values are not considered tolerable. Tractor working regime stays relatively constant if the tillage depth is changed.

Engine working regime does not change much with the depth change. The engine speed varies from 1720 to 1760 min^{-1} with the 85 to 100% of the motor load (Tab. 6). In this very regime tractor achieves the minimum fuel consumption per surface area although the hourly fuel consumption grows. After comparing the table 1 and table 6 it can be concluded that tractor engine speed is between maximum torque and maximum power regime but closer to the maximum power regime. Similar results were presented by *Kalk and Hülshberger* (1999), *Filipović et al.* (2004), and *Moitzi et al.* (2014).

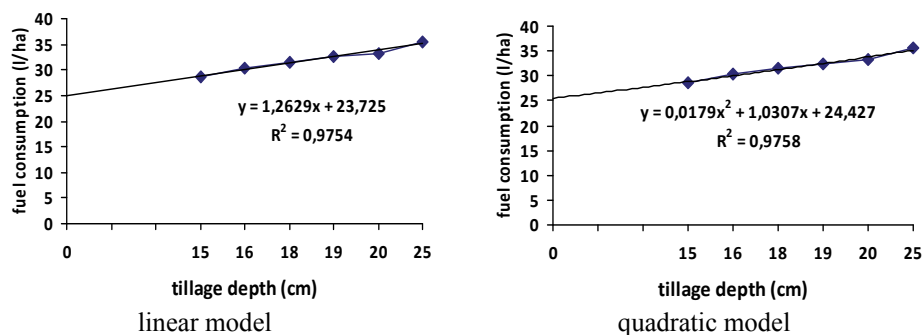


Figure 1 Fuel consumption per unit tilled area influenced by working depth

Table 6 presents the parameters obtained from the board computer of computers tractor.

Data presented in table 6 are different when compared with the table 4. The reasons are several. The first one is that the board compute calculates all necessary parameters based on the inserted input data. The primary input data is working width of the machine that is in aggregate with the tractor. In this case, this value was 4.2 m and this value is technical value. In real conditions this value was 3.95 m.

The next reason is that the board computer takes into account only the production working time and not total working time. This is the reason for having 15% difference (ASAE D 497.6, 2009) in the parameter when compared with the data from table 4.

Table 6 The tractor working parameters on the farm «Vrbovsko» from the board computer

No.	n_M [min ⁻¹]	regime engine [%]	v [km/h]	δ [%]	Q [l/h]	Q_{ha} [l/ha]	W_h [ha/h]
1.	1720	88	7.8	8	75	20.6	3.27
2.	1760	89	7.00	6	66	23.6	2.80
3.	1730	99	7.00	16	79	26.10	3.0
4.	1760	82	7.1	9	75	22.00	2.8
5.	1730	100	6.6	18	82.5	29.1	3
6.	1650	105	6.7	22	82.3	27.5	2.9
av.	-	94	7.00	13.20	76.60	24.80	2.96

The third thing is that, when hourly consumption and productivity are put in the relation, dimensionally consumption per surface area is obtained [l/ha]. This derives errors in the absolute amount and these errors can be taken as errors in the process of value rounding.

Nevertheless, the results are compatible on both basses even with the 7% difference in the working width and 15% difference in the total working time.

CONSLUSIONS

Reducing fuel consumption is an important goal in agriculture, since beside the economic effects also has the environmental effects, which are directly reflected to the reduction of the harmful products of combustion of diesel fuel that directly generate "greenhouse gases" and keeps the environment safe.

CASE STEIGER 400 on soil bulk density of 1.194 g/cm³ (humogley), in conditions of moisture content of 20% achieved a work rate of 2.4 ha/h with a fuel consumption of 31.8 l/ha. These values could be, in a part, corrected with minor overlap. The experiment overlap was 6%, while further reduction is possible only by GPS guiding.

Together with the soil conditions, very high impact on the fuel consumption has the tractor working regime. During the tractor exploitation care should be taken to the resistance that should be in the exploitation range of tractor pulling force which means well balanced agriculture machine unit. Futher more, the operating mode of the engine should be at the level of at least 85% of the load, because in this case the "skidder" tractors achieve the highest performance and lowest fuel consumption per unit area.

ACKNOWLEDGEMENTS

The authors wish to thank to the Ministry of education and science of Republic of Serbia for financing the TR 31051 Project.

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HARVEST RESIDUES BIO-TREATMENT AS A SOIL INCORPORATION IMPROVEMENT

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SUMMARY

The aim of this work is to determine the influence of biological preparation for cutting and breaking mechanical characteristics of overwintered winter wheat and oilseed rape plant residues, depending on biological preparation action period and compare research results with the same researches obtained in the natural conditions.

Experimental research of physical-mechanical properties of plant residues were carried out in 2013-2014 at laboratories of Institute of Agricultural Engineering and Safety of Aleksandras Stulginskis University, using experimental research machine „Instron 5960“.

The results of experimental investigations showed that forces required for termination and cutting of plant residues are lower, using biological preparation than without it. The time period over which plant residues are exposed in natural climatic conditions and/or biological preparation affects breaking and cutting properties of plant residues.

Key words: *harvest residues, biological preparation, breaking, cutting, knife, winter wheat, winter oilseed rape*

INTRODUCTION

Although tillage conservation and sowing technologies have many advantages (Morris et al., 2010; Rusu et al., 2011; Romaneckas et al., 2012; Soane et al., 2012), but also have some drawbacks. The main problem of zero-tillage technologies are that soil hardness and plant residues on soil surface decreases the quality of soil tillage and sowing. Decomposition period of crop residues depends on crop residue type and morphological part of the plant (Kriauciūnienė et al., 2012). Richly by plant residues coated soils often clogs tillage and sowing machines with ordinary coulters, deteriorates seedbed preparation, and increases working time and energy consumption (Šarauskis et al., 2014).

Examining the constructions of machines used in tillage conservation and sowing, it should be noted that soils with high concentrations of plant residues, are best suited for machines with disc coulters (Linke, 1998; Magalhaes et al., 2007; Šarauskis et al., 2010). Plant residues cutting quality is highly depending from the soil and plant residues physical and mechanical properties, disk coulters geometric parameters and technological modes. Disc coulters can't always cut plant residue. If the soil is moist and soft, so disc coulters instead of residue cutting stamp it into the soil formed furrow (Magalhaes et al., 2007). Disc coulters, which consist of two discs, the same plant residue (eg. straw) can cut in two different places. Coulters rolling in driving direction plant residues can be pushed into the soil by both disc blades. When coulters are in contact with the soil plant residues can be cut or stamped into the soil. Both discs swooping to the soil at the same time, not only cut plant residues, but also strain according to the convex soil's surface between discs. Soil resists plant residues swoop, so exceeded allowance for plant residue tensile stress, it may be terminated (Šarauskis et al., 2013).

Scientists from different countries (Linke, 1998; Tavakoli et al., 2009; Hemmatian et al., 2012; Šarauskis et al., 2013) doing research found that the force required for plant residues cutting or breaking depends on the type of plant, diameter of stem, length of the plant, moisture content, structure and elasticity of cells. Very important for cutting and breaking of plant residues are constructional and technological parameters of drill's/planter's components (Liu et al., 2007, 2010). Analysing mechanical characteristics of plant residues, another very important factor is how long the plant residues spend on the surface of the soil after harvesting. Duration of residues exposure to climate conditions significantly diminishes their mechanical properties (Linke, 1998; Šarauskis et al., 2013). However, there are not favourable conditions to wait until plant residues will lose its strengths mechanical properties in natural conditions that affect for technological processes of soil tillage and sowing machines work in the modern agriculture. Next crops are usually sown in the soil only a few weeks after the harvest of previous crop. For the purposes of zero tillage technology all plant residues of previous harvest remain on the surface of the soil and directly affect work process of agricultural machinery. Plant residues, which were on the soil surface in a short period, retain strong mechanical properties, why coulters often fail neither to cut neither to terminate plant residues. Therefore, to reduce the risk of these consequences, it is necessary to achieve accelerate mineralization and mechanical properties attenuation processes of plant residues. It could be used biological preparations with live nitrogen bacteria to activate these processes. In addition to that, biological preparations ensure long-term and stable yield of field crops, while maintaining clean environment, without causing damage for people (Ahmadi, 2010; Brussaard et al., 2007).

Biological preparations are generally used as nutrients to the soil and plants. Biological preparation composition consists of stem nitrogen-fixing bacteria *Azotobacter vinelandii* and biologically active substances, which affecting the structure of plant residues. Preparation accelerate mineralization of plant residues in the soil, living nitrogen-fixing bacteria at the same time stimulating decomposition of plant residues and attenuation processes of mechanical properties (Jakiene, 2011; Holtze et al., 2008; Ahmadi, 2010).

The aim of this work is to determine the influence of biological preparation on cutting and breaking mechanical characteristics of winter wheat and oilseed rape residues, depending on biological preparation action period.

MATERIALS AND METHODS

Experimental research of physical-mechanical properties of winter wheat and winter oilseed rape residues were carried out in 2013–2014 at laboratory of Institute of Agricultural Engineering and Safety of Aleksandras Stulginskis University. To achieve accordance with real conditions, harvest residues sampling were performed in autumn, immediately after harvest. Every plant residue have been divided into two parts and spread by combine harvester on the surface of uncultivated soil. One part of residues was left on the soil surface through the winter, exposed to climate conditions. Another part of residues was artificially sprayed with biological preparation „Azofix“, which spraying rate of $1.0 \text{ l} \cdot \text{ha}^{-1}$.

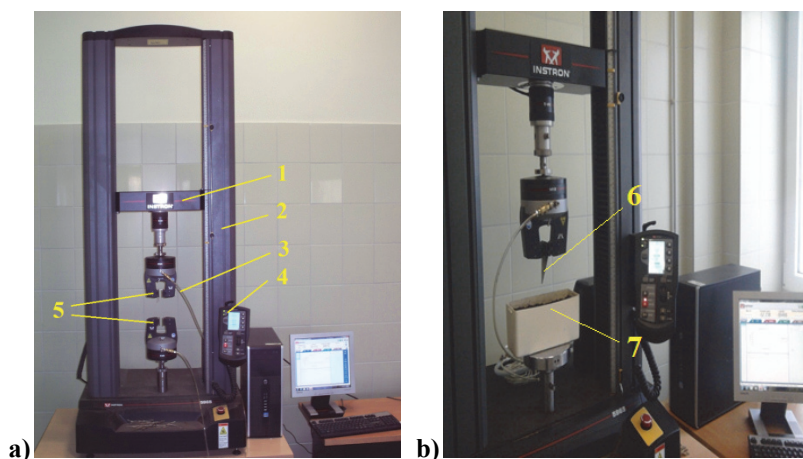


Fig. 1 Research of mechanical characteristics device ‘Instron 5960’: a) breaking; b) cutting; 1 – upper stroller; 2 – frame; 3 – tube of air supply to grabs; 4 – Control Panel; 5 – grabs of plant residues; 6 – knife; 7 – box with the soil

Experimental research of mechanical properties was carried out during the spring the spring, one month before sowing. First of all, samples of plant residues were weighed and dried to air-dry mass in the drying oven at 105°C . According to obtained results of sample

mass, humidity of plant residues was calculated. After that were doing an initial breaking and cutting mechanical properties researches of plant residues of winter wheat and winter oilseed rape. Experiments were doing in 3 weeks period, during which, one time in every 7 days, it was determine the biological impact of different plant residues breaking and cutting mechanical characteristics. Received characteristics have been compared with not affected properties of plant residues in natural climatic conditions. It is difficult to maintain the same humidity of different plant residues in natural climate conditions. So during each trial, moisture content of plant residues was repeatedly determined.

Research of breaking and cutting mechanical properties of plant residues were performed in experimental research machine 'Instron 5960'. Breaking force tests was carried out by plant residues consolidating between two jaws (Fig. 1a) and pulling its by velocity of $10 \text{ mm} \cdot \text{min}^{-1}$. Cutting tests of plant residues have been performed at two different knives, which imitated the disk coulters (Fig. 1b).

Both knives blades have been sharpened up 30° angle. Tests were carried out with light loam soil which humidity was 15%, and toughness – about 1 MPa. One vertically swooping knife cut plant residues perpendicularly to the surface of the soil, in the same way as do equal blade disc coulters blades (Fig. 2a). However, in order to improve the cutting quality of plant residues, in zero tillage machines very often are used disc coulters with corrugated blades. View of the fact, other cutting method was selected, when angle of the knife constructed 62° , by simulating plant residues cutting in the disc coulters blades notch (Fig. 2b). In this way was obtained the sliding cutting process of plant residues. Movement speed of the knife was $50 \text{ mm} \cdot \text{min}^{-1}$. In order to ensure equal physical properties of soil and experimental research conditions, after each test of plant residues cutting, the soil was re-compacted and measured its surface hardness and moisture content with penetrometer (Eijkkelkamp).

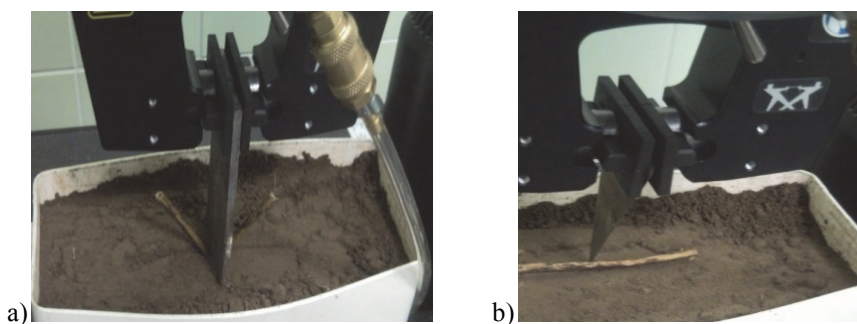


Fig. 2 Plant residue cutting with different knives: a) knife swooping vertically down; b) angled knife

Experimental research has been carried out periodically one time in every seven days. Both affected and not affected by biological treated residues breaking and cutting tests were carried out in 5 replications. Data obtained of the experimental researches were processed by mathematical-statistical methods, evaluating the substantial limit for LSD_{05} at 95% probability level (Tarakanovas et al., 2003).

RESULTS AND DISCUSSION

Winter wheat and winter oilseed rape residues which were used in experimental research average residues' dimensions and determined moisture content and the results of humidity in the periods of individual research are shown in Table 1. Analysing the results of moisture content (m.c.), it was observed that m.c. of winter wheat residues was significantly higher (about 3.3–4.5 times) just at the beginning of the research. Subsequently, the moisture content residues was from 7 to 10%. The residues' moisture content of winter oilseed rape changed less and in all periods ranged from 8 to 10%.

Table 1 Dimensions and moisture content of plant residues in period of research

Plant residue	Diameter mm	Length mm	Moisture content %			
			Start	After 1 week	After 2 weeks	After 3 weeks
			1	2	3	4
Winter wheat	4.0±0.4	100±2.6	33±1.4	10±0.6	7±0.3	7±0.2
Winter oilseed rape	3.0±0.3	100±2.7	10±0.5	10±0.4	9±0.4	8±0.3

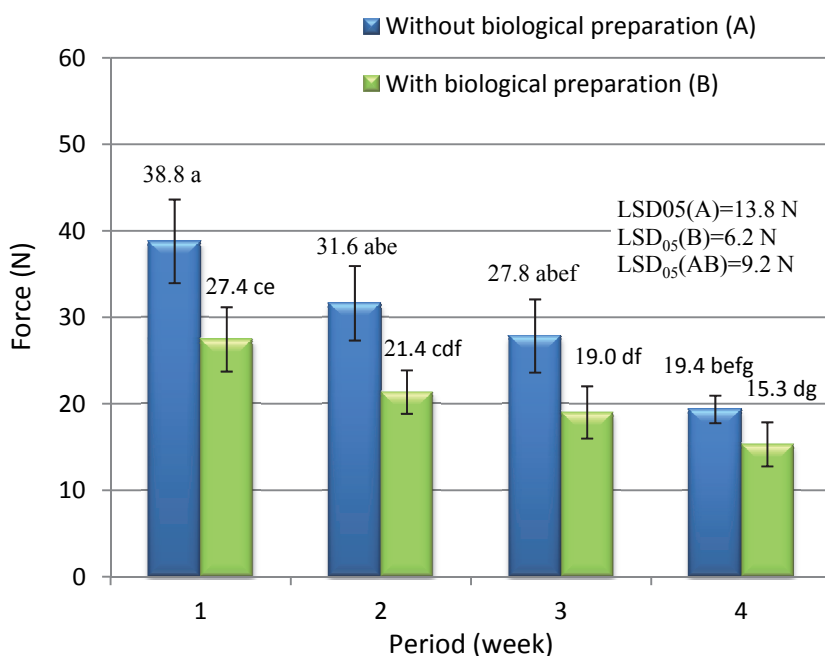


Fig. 3 Influence of biological preparation and its action period on breaking force of exposed winter wheat residues

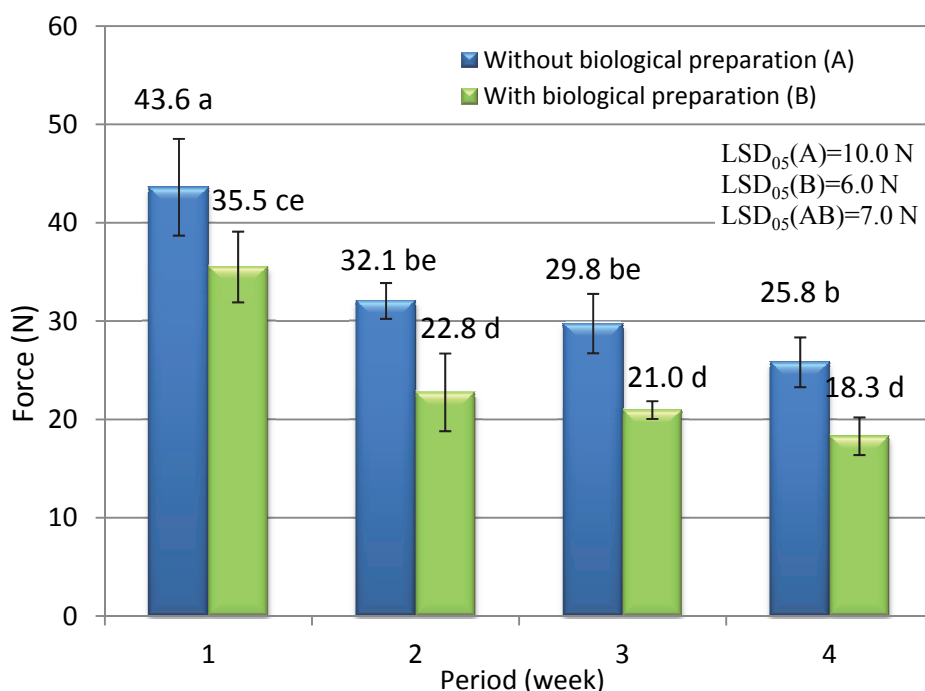


Fig. 4 Influence of biological preparation and its action period on breaking force of exposed winter oilseed rape residues

Experimental research, which was conducted in the spring, suggest, that the biological treatment influences decreasing of initial mechanical properties of winter wheat and winter oilseed rape residues. Winter wheat residues biological treated, significantly decreased breaking strength compared to plant residues exposed to climate conditions (Fig. 3). Lengthening the period of winter wheat residues exposure to climate conditions breaking strength decreased in both cases (treated and untreated). Analogical results were obtained during experimental researches with residues of winter oilseed rape (Fig. 4). Statistical analysis of the survey results shows that final force differences were substantial between the biological preparation treated and not treated residues of winter oilseed rape. Comparing the peak forces of winter wheat and winter rape, in all cases to break residues of winter rapeseed requires more force than to break residues of winter wheat.

Influence of biological preparation on exposed winter wheat residues cutting with different knives was determined and showed. When swooping knife cut vertically (Fig. 5) it is needed force from 70.3 N (at the beginning) to 33.1 N (after 3 weeks) to cut plant residues, which were sprayed with biological preparation, and to cut the exposed winter wheat residues without biological preparation needed force of 71.8 N to 45.5 N. The essential force difference was determined after 3 weeks. When swooping knife cut angled (Fig. 6) in all cases it was needed less force to cut overwintered winter wheat residues

comparing when swooping knife cut vertically. After 1, 2 and 3 weeks was determined an essential influence of biological preparation for plant residues cutting with this knife.

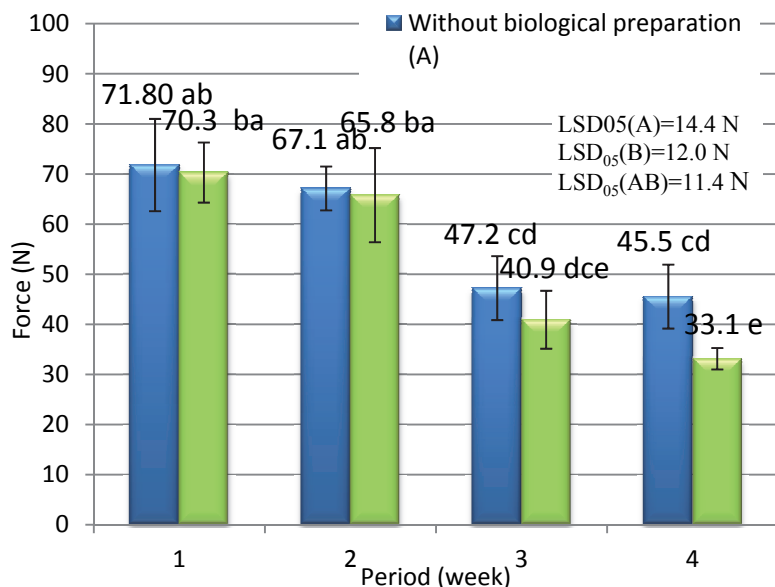


Fig. 5 Influence of biological preparation and its action period on cutting force of exposed winter wheat residues when using vertical knife

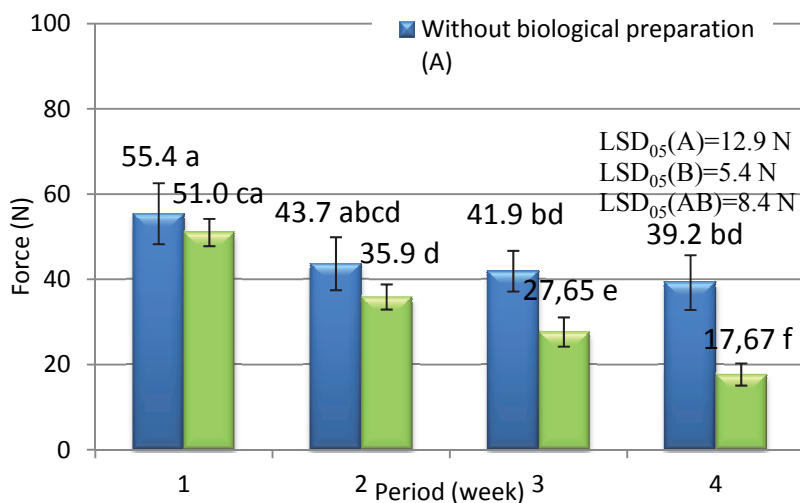


Fig. 6 Influence of biological preparation and its action period on cutting force of exposed winter wheat residues when using angled knife

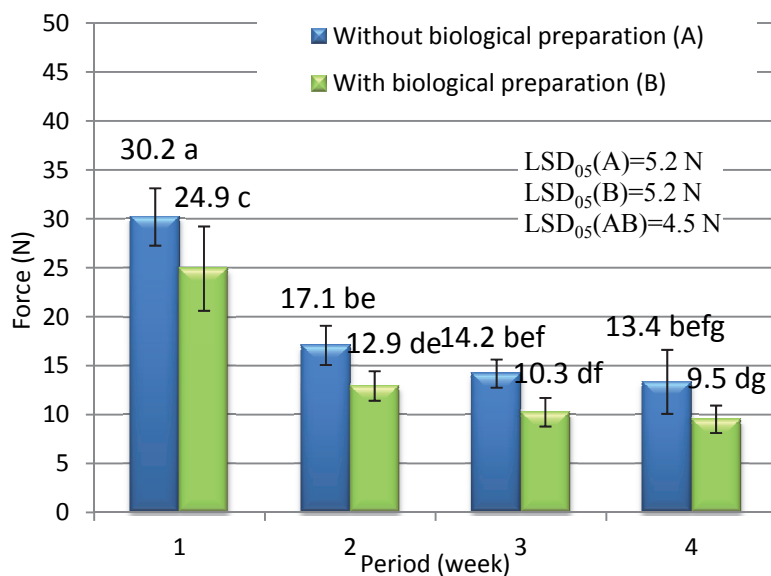


Fig. 7 Influence of biological preparation and its action period on cutting force of exposed winter oilseed rape residues when using vertical knife

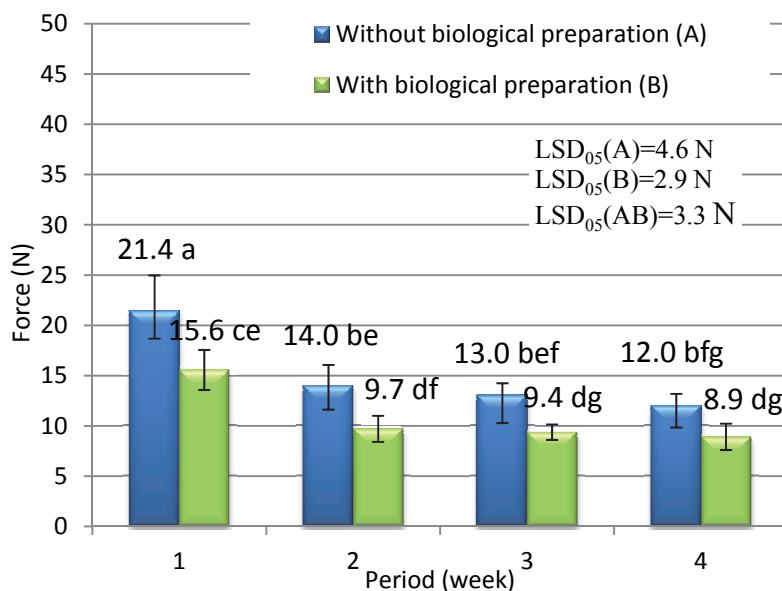


Fig. 8 Influence of biological preparation and its action period on cutting force of exposed winter oilseed rape residues when using angled knife

After cutting research with winter oilseed rape, were noticed that to cut residues of overwintered winter oilseed rape need averaged from 2 to 4 times less force than winter wheat residues. An essential influence of biological preparation cutting with vertically swooping knife was determined only at the beginning of trials (Fig. 7). The results of researches in subsequent period indicate that the biological preparation reduces cutting force needed to cut winter oilseed rapeseed residues, but differences weren't significant. Using an angled knife enable sliding technological process of cutting. Therefore, lower force was needed for climate conditions exposed residues of winter oilseed rape cutting (Fig. 8) than cutting using vertical knife.

Influence of biological treatment when using angled knife was seen throughout all research period, but substantial cutting force reduction was established only at the beginning of trials, after one and two weeks.

In summarising the research results and comparing it with other authors (Linke, 1998; Tavakoli et al., 2009; Liu et al., 2007; Liu et al., 2010) observations, it can be stated that type of plant residues, time of exposure plant residues to climate conditions, biological preparation and its action period, constructional parameters of cutting knives influence changes of plant residues mechanical characteristics, like peak breaking and cutting forces.

CONCLUSIONS

1. Biological preparation usage promotes the weakening of mechanical properties of plant residues. Overwintered and bio-treated winter wheat residues decrease breaking force within range of 26 – 47%, while winter oilseed rape residues decrease – from 22 to 42% comparing with not treated plant residues.
2. Prolonging the plant residues exposure to climate conditions period, decreases braking and cutting force for residues of winter wheat and winter oilseed rape.
3. Irrespective of used bio-treatment, increasing from 2 to 33 % of braking force was evidenced at climate conditions exposed winter oilseed rape residues, than at winter wheat residues. On the contrary cutting climate exposed winter oilseed rape residues required in average 2 to 4 times lower force, than winter wheat residues.
4. Using angled knife for cutting climate exposed winter wheat and winter oilseed rape residues at soil moisture content close on 15% and compaction about 1.0 MPa. needed lower force, than vertical knife.

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THE EFFECT OF TILLAGE TECHNIQUES, TEMPERATURE AND PRECIPITATION ON CO₂ EMISSIONS FROM LIGHT SOIL

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SUMMARY

*Three years study on the effect of different soil tillage systems on CO₂ emissions from the dystic brown alluvial soil was conducted on the experimental field near Podova (46° 25' 30" N, 15° 42' 35" E). In the rotation corn (*Zea mays* L.), winter wheat (*Triticum aestivum* L.) and winter raps (*Brassica napus* L.) the influence of conventional tillage with mouldboard plough and seedbed combination, non-conventional tillage with chisel plough and no-tillage with direct drill showed significant cyclic changes of CO₂ emissions, which are strongly related with the intensification of soil aeration. Thus, the maximal emission (16.9 $\mu\text{mol m}^{-2}\text{s}^{-1}$) was detected in October 2012 (winter raps) on chiseled plot; and minimal (0.29 $\mu\text{mol m}^{-2}\text{s}^{-1}$) in January 2012 on directly sown field planted with winter raps. However, specific annual precipitations caused even greater differences between CO₂ emissions than tillage itself. So, in 2012 the average annual emissions was 5.62 $\mu\text{mol m}^{-2}\text{s}^{-1}$ on ploughed plot, 5.03 $\mu\text{mol m}^{-2}\text{s}^{-1}$ on chisel parcel and 5.08 $\mu\text{mol m}^{-2}\text{s}^{-1}$ on no-tillage parcel; in 2011 the average annual emissions was 4.71 $\mu\text{mol m}^{-2}\text{s}^{-1}$ on ploughed parcel, 2.70 $\mu\text{mol m}^{-2}\text{s}^{-1}$ on chiseled field and 4.95 $\mu\text{mol m}^{-2}\text{s}^{-1}$ on direct seeded field; in 2010 the average annual emissions was 4.12 $\mu\text{mol m}^{-2}\text{s}^{-1}$ on ploughed parcel, 5.07 $\mu\text{mol m}^{-2}\text{s}^{-1}$ by using chisel and 4.10 $\mu\text{mol m}^{-2}\text{s}^{-1}$ by using no-tillage system.*

Key words: soil tillage, ploughing, chisel, direct drill, CO₂ emissions

INTRODUCTION

CO₂ flux in farmland is a significant component of the global carbon cycle, which is affected by present agricultural management practices. During recent decades, there has been an increasing interest in the global carbon dioxide budget (Houghton et al., 2001). The majority of our current knowledge on CO₂ fluxes and annual C budgets of croplands

originate from measurements conducted on the extensive monoculture agricultural landscapes such as maize and soybean rotations in North America (Hollinger et al., 2005).

Quantification of CO₂ exchange between ecosystems and the atmosphere has been achieved with the two widely accepted measurement techniques, namely the chamber (CT) and the eddy covariance (EC) techniques (Wohlfahrt et al., 2005). While the EC technique results best in open habitats (from hundreds of m² to km²) where fluxes are related to clearly defined vegetation types, the use of portable chambers allows direct evaluation of NECE (Net Ecosystem CO₂ Exchange), ecosystem respiration (Reco) and gross primary productivity (GPP) at small spatial scales (plot level), making it possible to find out useful differences within a heterogeneous landscape like mixed farming systems in the Slovenian agricultural landscape.

Research was focused on CO₂ emissions on alluvial soil within three years rotation corn (*Zea mays* L.), winter wheat (*Triticum aestivum* L.) and winter raps (*Brassica napus* L.) under Eastern Slovenia agricultural conditions. The aim of research was to (1) determine the seasonal patterns and magnitudes of CO₂ flux in the boundary layer of the atmosphere (2) to identify the weather conditions that regulate CO₂ emissions cycle. Primary assumption was that in specific agricultural system, differences in the timing and magnitudes lead to a high spatial variability of CO₂ exchange.

METHODS

Study site

The study was conducted on Dravsko polje, Eastern Slovenia close to the village of Podova (15° 42' 35" E, 46° 25' 30" N). The owner of the experimental field is agricultural company Perutnina Ptuj d.d. Conservation tillage with chisel plough has been applied since 2002. The total field area is 93.15 ha with the average elevation of 249.2 m and an average slope of 1% / 0.4° N.

Dravsko polje is defined as a flatland with terraces of fluvioglacial gravel that is very porous for water, at the altitude of 240 to 250 m. Soil is very shallow with a high percentage of skeleton, characterized as Dystric Fluvisol (FAO, 2006) with silt loam texture.

Table 1 Soil particle size distribution

Depth (cm)	Particle size				Texture
	0.2-2.0 µm	0.05-0.2 µm	0.002-0.05µm	<0.002 µm	
0-20	11	15	59	15	Silt loam
20-40	8	12	68	12	Silt loam

The average annual precipitation during the last 20 years amounts 915 mm ranging between 689 mm (2003) and 1078 mm (2009). Over 50 % of fall is during the vegetative period between June and September. The average annual temperature is 9.4 °C and 15.6 °C in the vegetation period average. The average summer temperature is 18.4 °C, and average winter temperature is -0.2 °C.

Description of the experimental plots

The experimental site comprised of three years rotation corn (*Zea mays L.*), winter wheat (*Triticum aestivum L.*) and winter raps (*Brassica napus L.*). In the middle part of the field a 11,760 m² (490 x 24 m) experimental parcel was selected and divided into three sub-parcels for applying different tillage techniques (conventional tillage with mouldboard plough and seedbed combination, non-conventional tillage with chisel plough and no-tillage with direct drill. In the first two tillage systems 40 % of winter wheat harvest residues and 100 % of winter raps and corn harvest residues were left on the field and incorporated in the soil, while in the case of direct drill residues remained on the top of the field.

Table 2 Field operations and application rates in production of corn (*Zea mays L.*)

Date	Field operation	Application rate ^{abc}
April 2 2010	Herbicide application ^c	Touchdown (5 l)
April 10 2010	Ploughing ^a	
April 12 2010	Secondary tillage ^a	
April 13 2010	Chisel ^b	
April 15 2010	Basic fertilization ^{abc}	PK 20:20 (300 kg) ; Slurry (18 m ³)
April 24 2010	Sowing ^{abc}	
April 24 2010	Fertilization ^{abc}	CAN 27 % (250 kg)
May 3 2010	Herbicide application ^{abc}	Lumax (3,7 l); Mustang (0,6 l)
June 5 2010	Fertilization ^{abc}	CAN 27 % (250 kg)
October 10 2010	Harvest ^{abc}	

^aconventional tillage, ^b non-conventional tillage, ^cno-till

Table 3 Field operations and application rates in production of winter wheat (*Triticum aestivum L.*)

Date	Field operation	Application rate ^{abc}
October 12 2010	Ploughing ^a	
October 14 2010	Secondary tillage ^a	
October 14 2010	Chisel ^b	
October 14 2010	Basic fertilization ^{abc}	KCl 60 % (150 kg)
October 15 2010	Sowing ^{abc}	
February 22 2011	Fertilization ^{abc}	Uniko 25.5 % (200 kg)
March 25 2011	Harrowing ^{abc}	
April 4 2011	Herbicide application ^{abc}	Hussar (0,1 l)+ Ogriol (1.0 l)
April 22 2011	Fertilization ^{abc}	CAN 27 % (190 kg)
May 5 2011	Fungicide ^{abc}	Amistar Extra (0,8 l) + Bulldock (0,3 l)
May 18 2011	Fertilization ^{abc}	Amonnitrate 34 % (100 kg)
May 30 2011	Fungicide ^{abc}	Prosaro (1.0 l) + Topsin M (1.1 l)
August 13 2011	Harvest ^{abc}	

^aconventional tillage, ^b non-conventional tillage, ^cno-till

Apart from tillage, all field operations and application rates remained the same in all parcels (Table 2). Fertilization of the fields, planting/harvesting dates, weed and pest control were done according to the GAP management. Basic fertilizer application was done 7–10 days before planting.

Table 4 Field operations and application rates in production of winter raps (*Brassica napus* L.)

Date	Field operation	Application rate ^{abc}
August 23 2011	Ploughing ^a	
August 23 2011	Secondary tillage ^a	
August 24 2011	Chisel ^b	
August 26 2011	Basic fertilization ^{abc}	NPK 10:20:20 (600 kg)
August 26 2011	Sowing ^{abc}	
August 26 2011	Fertilization ^{abc}	Uniko 25.5 % (200 kg)
Sept 7 2011	Herbicide ^{abc}	Aramo 2 l/ha
Sept 19 2011	Fungicide ^{abc} ; Insecticide ^{abc}	Caramba (1.2 l); Decis (0.3 l)
February 22 2012	Fertilization ^{abc}	CAN 27 % (180 kg)
March 23 2012	Fungicide ^{abc} ; Insecticide ^{abc}	Folicur EW250 (1.5 l)Fastac 100 EC (0.1 l)
July 5 2012	Harvest ^{abc}	

^aconventional tillage, ^bnon-conventional tillage, ^cno-till

Microclimate measurements

Between 2010 and 2013, air temperature, humidity and precipitation were continuously measured with 2 m high automatic weather stations (AWS, WS-GP1, Delta-T Devices Ltd., UK) on 'Letališče Maribor' weather station located approximately 3500 m from our experimental field. Each time during the CO₂ flux measurements additional data of temperature, pressure, relative humidity were taken in-situ.

Ecosystem CO₂ flux measurements

On each experimental parcel 3 sampling points were established 4–5 days before the start of CO₂ measuring flux by GPS Leica. CO₂ flux was measured by an ECHO device (Fig. 1) with two soil hoods - chambers (ECHO, Slovenia) every two weeks. Most CO₂ flux measurements were performed on cloudy or sunny days; practically no measurements were performed in rain. Each CO₂ chamber ($\Phi = 10$ cm, $V = 985$ cm³) was made of stainless steel. Using extension cylinder, chambers were closed/opened after the maximum set value was reached to assure continues constant CO₂ value. Measurements were carried out between 9–13 h (8 cycles per measurements).



Figure 1 ECHO device for measuring CO₂ gas exchange (left), soil hood for collecting the gases from the soil (right)

RESULTS AND DISCUSSION

Weather conditions

The weather conditions from 2010 to 2012 are summarized in Fig. 2, 4 and 6. In all years, air temperature increased steadily from spring to summer, reaching the maximum value of 22.2°C in July 2010, August 2011 (21.2°C) and July 2012 (21.7°C). Especially hot was the summer 2011. The minimal values was measured in January 2010 (-2.1°C), February 2011 (0°C) and February 2012 (-3.0°C), respectively. The annual amount of precipitation differs from year to year considerably; 729.9 mm in 2011 and 986 mm in 2010. The most intensive rainfall occurred during in the August 2010 (173.5 mm), July 2011 (133.9 mm) and September 2012 (154.4 mm).

Seasonal patterns of CO₂ fluxes

Fig 3, 5 and 7 represent monthly courses of CO₂ fluxes for three selected soil tillage systems from 2010 to 2012. CO₂ flux patterns varied significantly during the season, generally increasing from January to March very slowly, which is connected to cold weather conditions (low soil temperature) and small precipitations, respectively. Later, from April to May, the CO₂ flux development showed closer correlation with the precipitations then the temperature. These findings are more evident in the summer months of 2010 and 2012 in which the CO₂ flux was stagnating due to the drought till the bigger rains at the end of summer and begging of autumn. In November and December CO₂ flux decreased slowly and reached January's values without being influenced importantly by heavier precipitations. Thus, lower soil temperature plays again dominant role in CO₂ flux pattern. Each year the highest CO₂ flux was detected in different month and tillage system; in September 2010 the highest values was measured on 'chisel' parcels during the seedbed preparation for winter wheat, in March 2011 the maximal CO₂ flux (15.6 $\mu\text{mol m}^{-2} \text{s}^{-1}$) was measured on the 'no-till' parcel and in October 2012 16.9 $\mu\text{mol m}^{-2} \text{s}^{-1}$ was detected on the 'plough' parcels (winter raps).

The minimum CO₂ flux ($0.9 \mu\text{mol m}^{-2} \text{s}^{-1}$) was measured on the no-till parcels in February 2011; on the ploughed parcels in December 2011 ($0.40 \mu\text{mol m}^{-2} \text{s}^{-1}$) and $0.29 \mu\text{mol m}^{-2} \text{s}^{-1}$ in January 2012 on parcels 'chisel'.

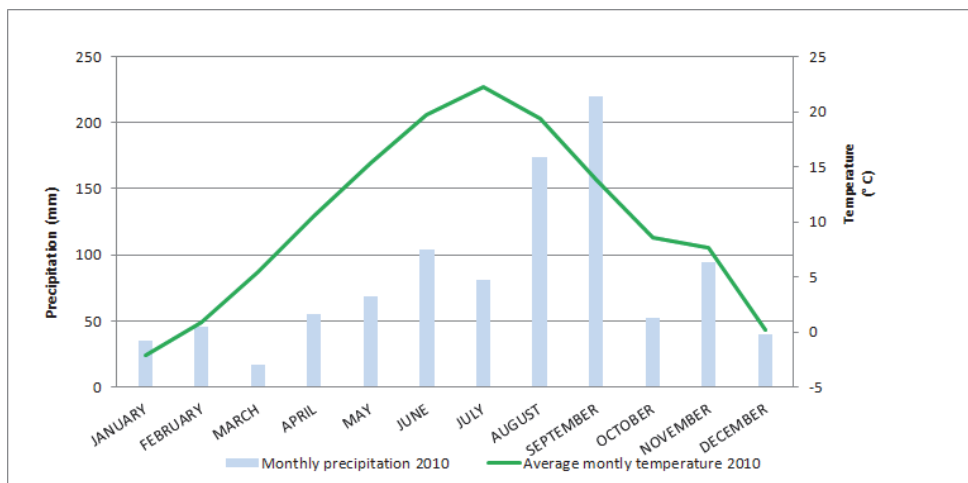


Figure 2 Monthly precipitation and average monthly temperature in 2010 (ARSO 2013)

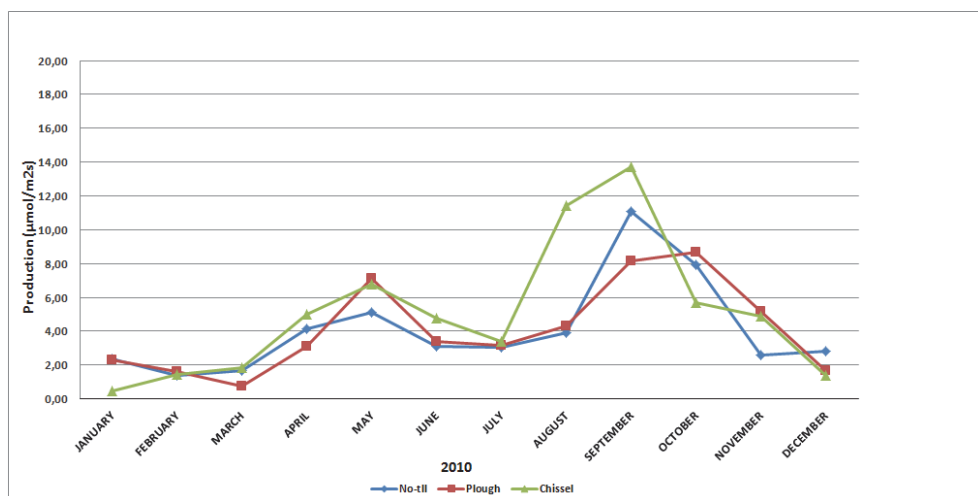


Figure 3 CO₂ emissions caused by different soil tillage in 2010

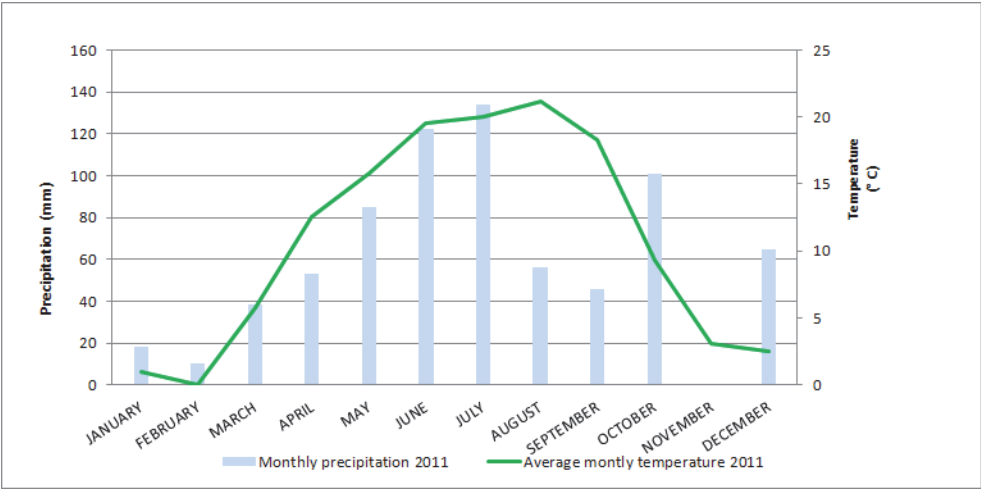


Figure 4 Monthly precipitation and average monthly temperature in 2011 (ARSO 2013)

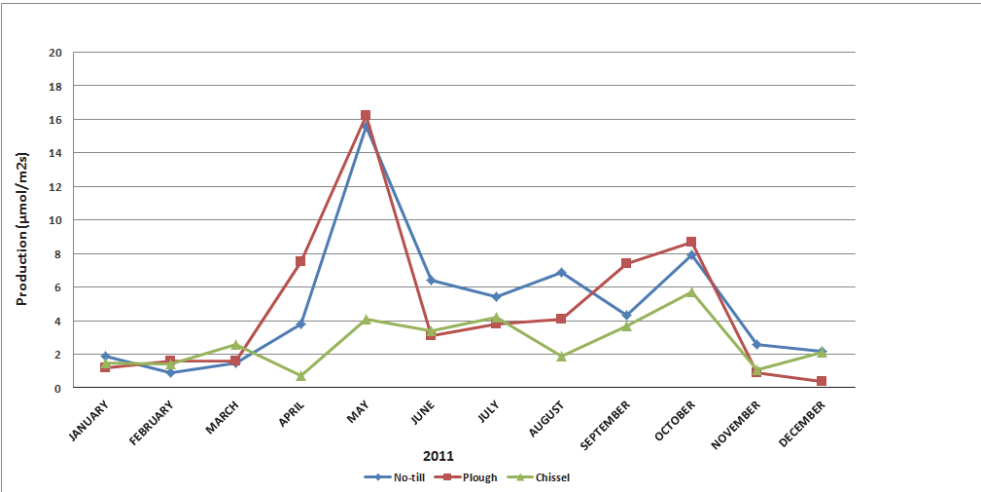


Figure 5 CO₂ emissions caused by different soil tillage in 2011

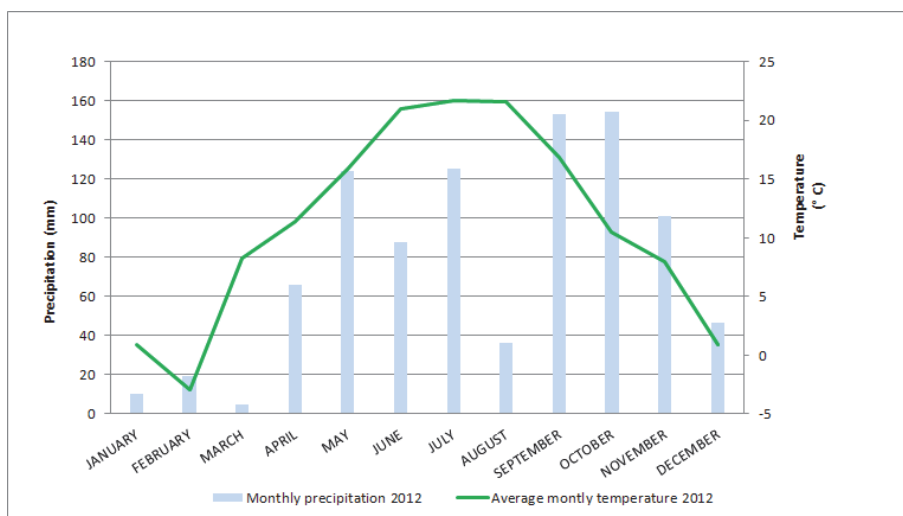


Figure 6 Monthly precipitation and average monthly temperature in 2012 (ARSO 2013)

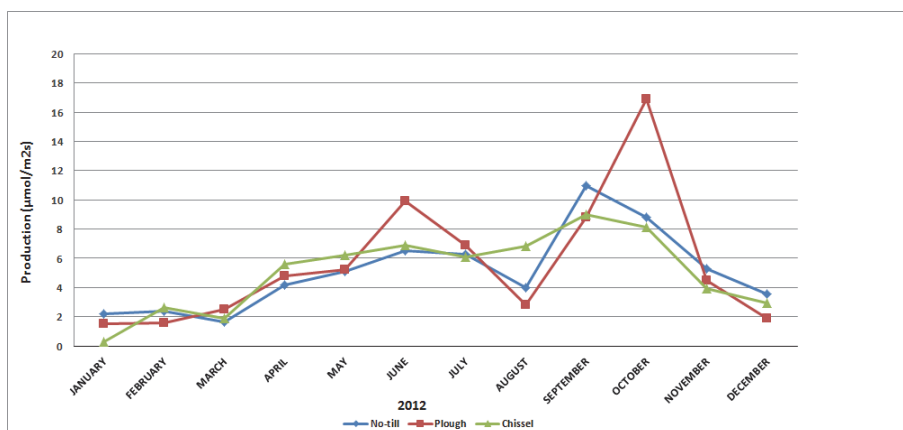


Figure 7 CO₂ emissions influenced by different soil tillage in 2012.

Yields

Table 5 represents the average yields of tested crops achieved by different soil tillage systems. In corn production the greatest average yield of 7,300 kg ha⁻¹ was achieved by chisel tillage system in 2010, followed by conventional tillage system with the average yield of 6,700 kg ha⁻¹ and no-till with 6,520 kg ha⁻¹. According to ANOVA, there was a statistically significant difference between the chisel and other two systems. The highest average yield of winter wheat was again recorded in chisel system with 7,241 kg ha⁻¹ and did statistically differ only from the no-till parcel (6,450 kg ha⁻¹). Also in the winter raps

the highest yield was measured by chisel tillage system (4,832 kg ha⁻¹), which again differed significantly from both other systems.

Table 5 The average yield on different tillage system.

Tillage system	Average yield (kg ha ⁻¹)		
	Corn (2010)	Winter wheat (2011)	Winter raps (2012)
No-till	6,520 ^b	6,450 ^b	3,910 ^b
Plough	6,700 ^b	6,914 ^a	4,211 ^b
Chisel	7,300 ^a	7,241 ^a	4,832 ^a

^{a, b} statistically significant at $p < 0.05$ (Duncan test).

CONCLUSIONS

The quantification of CO₂ fluxes between the soil and the atmosphere was measured by a chamber technique (CT) on the experimental field near Podova (Slovenia). In the rotation corn, winter wheat and winter raps, the effect of three different tillage systems showed no significant differences between the average annual CO₂ emission fluxes. For instance, in 2012 the average annual emissions was 5.62 $\mu\text{mol m}^{-2}\text{s}^{-1}$ on ploughed parcel, 5.03 $\mu\text{mol m}^{-2}\text{s}^{-1}$ on chisel parcel and 5.08 $\mu\text{mol m}^{-2}\text{s}^{-1}$ on no-tillage parcel, respectively. Thus, the intensive soil tillage on the ploughed parcel was proved to have the biggest effect on the soil mineralisation and CO₂ emission fluxes.

On the other hand, the specific annual weather conditions, especially precipitations, caused greater differences between CO₂ fluxes than tillage itself during the vegetation period. This was proved very evidently during the time of summer droughts in July 2010 and August 2012 and the first heavy rains coming afterwards. The temperature effects the CO₂ flux development more than precipitations in the cold period of the year, whereby in the spring months the temperature increase the CO₂ fluxes and in the late autumn decrease the CO₂ fluxes, respectively.

On the parcel with chisel tillage system the highest average yields were measured in all three years of rotation (corn 7,300 kg ha⁻¹, winter wheat with 7,241 kg ha⁻¹ and winter raps 4,832 kg ha⁻¹), which showed that with chisel plough the soil can be prepared for growing the plants at most appropriate way against all kind of weather extremes.

ACKNOWLEDGEMENTS

The results presented are an integral part of the project CRP V4-1062 entitled "Study of the impact of alternative tillage to improve soil fertility and increase the humus in the soil and reduce CO₂ emissions into the atmosphere", which is financed by the Slovenian Research Agency and the Ministry of Agriculture, Forestry and Food of the Republic of Slovenia. The authors also acknowledge the vital contributions made by Klemen Klaučič the production manager of the agricultural division in Perutnina Ptuj d.d. for supporting the experiments within his pre-fattening piglet facility.

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UTJECAJ TEHNIKE OBRADE TLA, TEMPERATURE I OBORINA NA EMISIJE CO₂ IZ LAKIH TLA

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SAŽETAK

U trogodišnjoj studiji na pokusnom polju u blizini sela Podova (46 ° 25 '30 "N, 15 ° 42' 35" E) proučavan je utjecaj različitih sustava obrade tla na emisije CO₂ iz distričnih smedih aluvijalnih tla. U rotaciji kukuruz (Zea mays L.), ozima pšenica (Triticum aestivum L.) te ozima repica (Brassica napus L.) primijenjena je konvencionalna obrada tla sa lemešnim plugom te sjetvenom kombinacijom, nekonvencionalnih obrada sa gruberom te sustav nulte obrade tla pomoću sijačice za direktnu sjetvu. Istraživanja su pokazala značajne cikličke promjene emisija CO₂ iz tla tijekom cijele godine, koje su snažno povezane sa intenzivnim miješanja tla plugom te sjetvenom kombinacijom. Prema tome, najviša izmjerene emisija ($15,60 \mu\text{mol m}^{-2}\text{s}^{-1}$) bila je u ožujku 2011 nakon pripreme tla za sjetvu kukuruza plugom te sjetvenom kombinacijom; minimalna emisija ($0,29 \mu\text{mol m}^{-2}\text{s}^{-1}$) izmjerena je u siječnju 2012 o sustavu no-till sa izravnom sijačicom. Međutim, prosječna godišnja emisija CO₂ u veliko zavisi i od vremenskih uvjeta, posebice oborina. Tako iznose prosječne godišnje emisije u 2012 godini $5,62 \mu\text{mol m}^{-2}\text{s}^{-1}$ u sustavu sa oranjem, $5,03 \mu\text{mol m}^{-2}\text{s}^{-1}$ u sustavu sa gruberom te $5,08 \mu\text{mol m}^{-2}\text{s}^{-1}$ u sustavu nulte-obrade; u 2011 prosječne godišnje emisije bile su $4,71 \mu\text{mol m}^{-2}\text{s}^{-1}$ u sustavu sa oranjem, $2,70 \mu\text{mol m}^{-2}\text{s}^{-1}$ u sustavu sa gruberom te $4,95 \mu\text{mol m}^{-2}\text{s}^{-1}$ u sustavu nulte-obrade. U 2010 godini prosječne godišnje emisije bile su $4,12 \mu\text{mol m}^{-2}\text{s}^{-1}$ kod oranja, $5,07 \mu\text{mol m}^{-2}\text{s}^{-1}$ kod upotrebe grubera te $4,10 \mu\text{mol m}^{-2}\text{s}^{-1}$ u sustavu nulte obrade tla.

Ključne riječi: obrada tla, oranje, gruber, sijačica za direktnu sjetvu, emisija CO₂



VPLIV RAZLIČNIH NAČINOV OBDELAVE TAL NA OKOLJSKI ODTIS PRI OZIMNI PŠENICI

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POVZETEK

Okoljski odtis predstavlja biološko produktivno površino tal in morja, ki ga potrebujemo za zadovoljitev naših potreb in za porabo onesnaženja, ki ga proizvedemo pri našem delu oziroma dejavnosti. V poskusu smo ugotavljali, kako različni načini obdelave tal pri pridelavi ozimne pšenice vplivajo na okoljski odtis pri konvencionalni, konzervirajoči obdelavi tal in pri direktni setvi. Cilj poskusa je, s pomočjo spletnega programa ugotoviti, kateri način obdelave tal je najbolj primeren za pridelavo ozimne pšenice ob doseganju največjega pridelka in najmanjšega okoljskega odtisa. Na posestvu je bil izveden poljski poskus na dveh parcelah z različnim tipom tal. Na obeh lokacijah so bili izvedeni trije različni načini obdelave tal. Največji okoljski odtis pustimo s konzervirajočo obdelavo tal in znaša na Centru 157,3 ha in na Gorici 134,8 ha. Najmanjši odtis pa pustimo pri direktni setvi in znaša na Centru 120,2 ha in Gorici 113,7 ha. Optimalen način obdelave tal, glede na okoljski odtis, je konvencionalna obdelava tal, saj spusti v okolje srednjo vrednost ogljika in zadovoljiv končni pridelek.

Ključne besede: okoljski odtis / ozimna pšenica / obdelava tal

UVOD

Okoljski odtis (ecological footprint) predstavlja biološko produktivno površino kopnega in morja. Biološko produktivno površino potrebujemo za zadovoljitev naših potreb in za razgradnjo onesnaževanja, ki ga proizvedemo pri našem delu ali dejavnosti. Enota za okoljski odtis je globalni hektar na prebivalca (gha). Z drugimi besedami bi lahko rekli, da je okoljski odtis vpliv posameznika na planet. Prav tako je okoljski odtis kazalec trajnostnega razvoja, ki se spreminja glede na življenjski slog posameznika. Z njegovim izračunom, prilagojenim našim potrebam, si lahko zagotovimo boljši način življenja, boljše poslovanje naše dejavnosti, izboljšamo proizvodne procese, in kar je najpomembnejše, si

lahko zmanjšamo stroške pridelave (Ohl in sod. 2008). V kmetijstvu običajno uporabljamo za izračun okoljskega odtisa podatke pridobljene v drugih državah, organizacijah FAO in statistične podatke. Ti podatki so dokaj netočni in tako ne moremo izračunati natančnega odtisa. Za bolj natančne izračune se poslužujemo vrednotenja življenjskega cikla proizvoda (Life Cycle Assessment, LCA) in ocene okoljske obremenitve, ki jo povzroči neka dejavnost, proces ali izdelek (Stajanko in Vindiš 2013).

V poskusu smo glavni poudarek naredili na treh načinih obdelave tal. Ti so konvencionalna, konzervirajoča obdelava in direktna setev brez obdelave. Pri raziskovanju različnih načinov obdelave tal naletimo tudi na veliko različnih poimenovanj, saj vsak strokovnjak pogosto gleda na obdelavo le s stališča svoje stroke in je tako težko najti skupen izraz za način obdelave. Pri poimenovanju konvencionalne obdelave so si strokovnjaki enotni. Nekaj težav je pri konzervirajoči obdelavi tal, saj se zanjo uporablja več izrazov: reduciran način, racionalni način in trajnostni način obdelave tal (Šimenc 2009).

Konvencionalna obdelava tal

Značilno za konvencionalno obdelavo tal je obdelava z oranjem. Plug brazdo obrne, zrahlja in nekoliko zdrobi odrezan del tal, zaorje tudi žetvene ostanke, semena plevla, plevel, hlevski gnoj in podorine, če je potrebno. Osnovni obdelavi tal oziroma oranju sledi dopolnilna obdelava, pri kateri tla zravnamo, večje grude tal zdrobimo predvsem na površju tal in po potrebi zgostimo plast tal pod setvenim horizontom. Dopolnilni obdelavi sledi setev, žetvi oziroma spravi lu žit pa strniščna obdelava. Med setvijo in žetvijo po potrebi opravimo določene posege v posevek in tla, npr. brananje, valjanje, okopavanje posevkov (Mrhar 2002).

Konzervirajoča obdelava tal

Konzervirajoča obdelava tal je obdelava brez uporabe pluga. Za njo ostane po končani obdelavi in setvi več kot 30 % obdelane površine pokrite z rastlinskimi ostanki prejšnje poljščine. Konzervirajočo obdelavo tal sestavljajo štirje podsistemi ter različne kombinacije med njimi (Mrhar 2002). Ti so:

- No till ali setev v neobdelana tla. V času po spravi lu prejšnje poljščine in pred novo setvijo ni posegov v tla. Sejemo v 1–3 cm široke vrste.
- Strip till ali setev v pasove obdelana tla. Tudi v tem primeru ne posegamo v tla po spravi lu prejšnje poljščine. Sočasno z novo setvijo tla po pasovih plitvo obdelamo za vsako setveno cev posebej.
- Mulch till ali setev v plitvo in na široko obdelana tla. V presledku med vegetacijama ostane zemlja nedotaknjena – pustimo jo na miru, neposredno pred novo setvijo pa jo obdelamo.
- Ridge till ali setev npr. koruze, soje ter podobnih poljščin na trajno oblikovanje ozke lehe, ki so dvignjene nad okoliškim zemljiščem najmanj 20 cm. Obdelava tal zajema le morebitne posege zaradi popravila leh.

Neposredna setev brez obdelave tal

V Sloveniji še ne tako poznana obdelava tal, je v svetu precej razširjena. To je setev v neobdelano zemljo ali direktna setev, ki je še v razvoju. Z njo lahko povečamo delež vode v tleh in zmanjšamo erozijo tal. S tem načinom pa lahko povečamo tudi število mikroorganizmov, vendar se v nekaterih primerih poveča uporaba herbicidov. Neposredna ali direktna setev je postopek z najmanjšim posegom v strukturo tal. Naredimo samo plitve brazde, kamor odložimo seme. Za ta postopek uporabljamo posebne sejalnice s kolustastimi sejalnimi lemeži in rezalnimi diski za rastlinske ostanke. Po nekaj letih uporabe direktne setve postanejo tla podobna travniku (Poje 2011).

Če se odločimo za kmetovanje brez obdelave tal, bomo v prvih letih naleteli na nekaj težav, ki vplivajo na količino pridelka. Te težave so: upravljanje z organskimi ostanki, povečan razvoj plevelov in okužbe z nekaterimi boleznimi (fuzarioza). Težave bomo prebrodili s premišljenim kolobarjenjem, vključevanju dosevkov, ki dodatno izboljšujejo strukturo tal in z manjšimi posegi v tla. Priderek je manjši na začetku uvažanja direktne setve, ampak se kasneje poveča (Rosner in sod. 2003).

Cilj raziskave je, da s primerjanjem različnih podatkov o načinu obdelave tal pridobimo podatke o okoljskem odtisu. Z rezultati okoljskega odtisa želimo ugotoviti, kateri način obdelave tal je bolj primeren pri pridelovanju ozimne pšenice in s katerim načinom spustimo čimmanj ogljika v okolje ob doseganju zadovoljivega pridelka.

METODE DELA

Spletni program za izračunavanje okoljskega odtisa

Okoljski odtis smo izračunali s pomočjo spletnega programa, ki ga je razvil dr. Michael Narodslawsky s sodelavci s tehnične univerze v Gradcu. Sustainable Process Index (SPI®) je eden od načinov ekološkega vrednotenja s pomočjo LCA pristopa, ki ga najdemo na spletni strani <http://www.fussabdrucksrechner.at/en/calculation/agriculture>.

Fig. 1 Sub-program plant protection and fertilization

Program je sestavljen iz šestih različnih delov, pri katerih v vsakega posebej vnašamo podatke vseh opravil in nam na koncu programa izračunajo podatke o vrednosti okoljskega odtisa za določeno opravilo. Slika 1 prikazuje način vnašanja podatkov o uporabi fitofarmacevtskih sredstev in gnojil. Na podlagi teh podatkov program izračuna okoljski odtis za posamezno sredstvo oziroma gnojilo, ki smo ju uporabili v poskusu.

Stroji uporabljeni v poskusu

Iz preglednice 1 je razvidno, katere stroje in priključke smo uporabili v poskusu. Pri konzervirajoči obdelavi tal smo uporabili traktor Challenger MT 875B.

Priključek, s katerim smo upravljali s traktorjem Challenger je gruber Väderstadt Top Down. Gruber obdeluje tla na delovni globini 15 cm. Pri konvencionalni obdelavi tal smo tla preorali z štiri brazdnim obračalnim plugom Regent na delovni globini 20 cm.

Poskus je bil izveden na dveh parcelah (gorica in center) za tri načine obdelave tal. Preglednica 1 še prikazuje delovne storilnosti in porabo goriva za posamezna opravila. Ti podatki so ključni za izračun okoljskega odtisa.

Table 1 Machines used in the experiments

TASK	TRACTOR	IMPLEMENT	WORKING EFFICIENCY (ha/h)		FUEL CONSUMPTION (l/h)	
			Gorica	Center	Gorica	Center
Conservation tillage						
Basic tillage	Challenger MT 875B	Väderstad Top Down 6m	4,2 ha/h	4 ha/h	57 l/h	59 l/h
Conventional tillage						
Basic tillage	Fendt 818	Plough Regent 4B	0,5 ha/h	0,4 ha/h	12 l/h	15 l/h
Pre-sowing treatment	Fendt 818	Harrow Kverneland 4m	0 ha/h	1,3 ha/h	0 l/h	11 l/h
All tillages						
Spraying	Fendt 309	RAU 24 m	14 ha/h	14 ha/h	7 l/h	7 l/h
Fertilizing	Fendt 309	Amazone ZA-M 24 m	14 ha/h	14 ha/h	7 l/h	7 l/h
Sowing	Fendt 930	Amazone combination 6m	4 ha/h	3,8 ha/h	19 l/h	21 l/h
Weeding	New Holland M 160	Einböck 24 m	10 ha/h	10 ha/h	8 l/h	8 l/h

Agrotehnični ukrepi uporabljeni v poskusu

Prvi poskus smo izvajali kraju Pesnica pri Mariboru na parceli Center. Koordinate njive so 45°35'58"N in 15°40'36"E. Poskus smo opravljali na težkih tleh, ki jih imenujemo hipogelj. Celotna površina njive je 13,57 hektarjev. V preglednici 2 imamo navedena vsa opravila, vrsto repromateriala in količino za prvi poskus na parceli Center.

Table 2 Agro-technical measures used in experiment 1

Work task	Repromaterial	Quantity kg/ha	Notes
Basic fertilizing	KCl 60 %	150 kg	
Sowing	Wheat 'Orvantis'	170 kg	
1. fertilizing	Uniko 25,5 % of nitrogen	200 kg	
Weeding			
1. spraying	Hussar + Ogriol	0,1 l + 1 l	Weed > 10 %
2. fertilizing	Uniko 25,5 % of nitrogen	200 kg	
2. spraying	Amistar Extra + Bulldock	0,8 l + 0,3 l	Mildew > 30 %
3. fertilizing	Amonnitrat 34 %	100 kg	
3. spraying	Prosaro + Topsin M	1 l + 1,1 l	<i>Fusarium</i> > 5 %

Drugi poskus smo izvajali v občini Rače – Fram na parceli Gorica. Parcela se nahaja na koordinatah 46°25'30"N in 15°42'35"E v kraju Gorica. Tip tal so lahka distrična tla. Njiva v celoti zajema 93,15 hektarjev.

V preglednici 3 imamo navedena vsa opravila za poskus 2 na parceli Gorica.

Table 3 Agro-technical measures used in experiment 2

Work task	Repromaterial	Quantity /ha	Notes
Sowing	Wheat 'Illico'	175 kg	
1. fertilizing	Uniko 25,5 % of nitrogen	170 kg	Nmin 22,49 kg
Weeding			
1. spraying	Sekator + Mustang + Ogriol	0,15 l + 0,5 l + 1 l	Weeds > 10 %
2. fertilizing	Last N	20 kg	
3. fertilizing	Uniko 25,5 % of nitrogen	200 kg	
2. spraying	Amistar extra	1 l	Mildew > 30 %
3. spraying	Prosaro + Topsin M + Bulldock	1 l + 1,1 l + 0,3 l	<i>Fusarium</i> > 3 %

REZULTATI Z RAPRAVO

V poskusu 1 smo ugotavljali, kakšen okoljski odtis je pustila pridelava ozimne pšenice 'Orvantis' na parceli Center pri vsakem načinu obdelave tal.

Iz preglednice 4 je razvidno, da je bil največji pridelek 6814 kg/ha na parcelah, obdelanih v postopku konzervirajoče obdelave in se ni razlikoval od pridelka na parceli konvencionalne obdelave. Najmanjši pridelek je na parceli neposredne obdelave in se loči od ostalih dveh parcel.

Table 4 Yield at experiment 1 (Center) in kg/ha

TILLAGE METHODS	Yield in kg/ha
Conventional tillage	6721
Conservation tillage	6814
Direct sowing	6272

Konvencionalna obdelava tal na parceli Center

Iz preglednice 5 lahko razberemo podatke o okoljskem odtisu posamezne delovne operacije za konvencionalno obdelavo tal na parceli Center. Podatki iz preglednice kažejo, da so največji odtis pustila opravila, pri katerih smo uporabljali gnojila. Najmanjši okoljski odtis smo dobili pri osnovni obdelavi tal (oranju) in znaša 0,6 ha. Sledi predsetvena obdelava tal z okoljskim odtisom 1,4 ha in nato škropljenje s herbicidi. Pri opravih, kjer smo uporabili gnojila, se odtis bistveno poveča. Pri vseh teh opravih smo povzročili od 5,1 ha do 14,8 ha okoljskega odtisa. Največji okoljski odtis smo povzročili pri gnojenju z gnojilom Uniko 25,5 % in znaša 14,7 ha.

Table 5 Ecological footprint for conventional tillage at Center

Work task	Machines [ha]	Repromaterial [ha]	Total [ha]
Basic tillage	0,6	/	0,6
Pre-sowing treatment	1,4	/	1,4
1. fertilizing	0,1	5,0	5,1
Sowing	7,3	/	7,3
2. fertilizing	0,1	14,7	14,8
Weeding	8,0	/	8,0
Herbicide	0,1	2,9	3
3. fertilizing	0,1	14,7	14,8
Fungicide + insecticide	0,1	1,9	2
4. fertilizing	0,1	7,4	7,5
Fungicide	0,1	3,3	3,4
TOTAL:	18	49,9	67,9

Konzervirajoča obdelava tal na parceli Center

V preglednici 6 so predstavljeni podatki za konzervirajočo obdelavo tal na parceli »Center«. Zaradi težkih tal je bila dodatno opravljena predsetvena obdelava.

Table 6 Ecological footprint for conservation tillage at Center

Work task	Machines [ha]	Repromaterial [ha]	Total [ha]
Basic tillage	20,80	/	20,80
Pre-sowing treatment	1,4	/	1,4
1. fertilizing	0,1	5	5,1
Sowing	7,3	/	7,3
2. fertilizing	0,1	14,7	14,8
Weeding	8	/	8
Herbicide	0,1	2,9	3
3. fertilizing	0,1	14,7	14,8
Fungicide + insecticide	0,1	1,9	2
4. fertilizing	0,1	7,4	7,5
Fungicide	0,1	3,3	3,4
TOTAL:	38,2	49,9	88,1

Na posestvu izvajajo konzervirajočo obdelavo tal že 7 let. Pri vrednostih okoljskega odtisa za konzervirajočo obdelavo tal v preglednici 6 vidimo, da je najmanjši odtis v okolje pustila predsetvena obdelava tal, katera je bila opravljena zaradi težkih tal in znaša 1,4 ha. Skupni odtis gnojil in pesticidov je enak kot pri konvencionalni obdelavi, saj smo uporabili iste stroje ter enako količino in vrsto repromateriala. Za razliko od gnojil in pesticidov se je povečal izračunan odtis strojnih opravil. Ta se je namreč povečal za približno 20 ha, saj je obdelava tal s stroji za osnovno obdelavo tal doprinesla večjo obremenitev okolja v primerjavi s konvencionalno obdelavo tal, kar lahko povezujemo z večjo porabo goriva, močnejšim traktorjem in zahtevnejšim strojem, kar je v postopku izdelave pomenilo večji odtis.

Neposredna setev na parceli Center

Preglednica 7 prikazuje podatke o okoljskem odtisu za direktno setev ozimne pšenice za parcelo Center.

Pri direktni setvi ozimne pšenice vidimo, da imamo skupno manj odtisa, saj pri tem tal ne obdelujemo predhodno, ampak pšenico posejemo direktno v neobdelana tla. Največji odtis, ki znaša 14,8 ha, povzroči gnojenje z gnojilom Uniko 25,5 %. Najmanjši odtis pa pusti škropljenje s herbicidi in znaša od 2 ha do 3,4 ha.

V poskusu 2 smo ugotavljali kakšen okoljski odtis je pustila pridelava ozimne pšenice 'Illico' na parceli Gorica.

Table 7 Ecological footprint for direct sowing at Center

Work task	Machines [ha]	Repromaterial [ha]	Total [ha]
Sowing	7,3	/	7,3
1. fertilizing	0,1	14,7	14,8
Weeding	8	/	8
Herbicide	0,1	2,9	3
1. fertilizing	0,1	14,7	14,8
Fungicide + insekticide	0,1	1,9	2
1. fertilizing	0,1	7,4	7,5
Fungicide	0,1	3,3	3,4
TOTAL:	15,9	44,9	60,8

V preglednici 8 je prikazan končni pridelek ozimne pšenice za vsak način obdelave tal posebej.

Table 8 Yield at experiment 2 (Gorica) in kg/ha

TILLAGE METHODS	Yield in kg/ha
Conventional tillage	6946
Conservation tillage	7241
Direct sowing	6450

Konvencionalna obdelava tal na parceli Gorica

V preglednici 9 so prikazani podatki o okoljskem odtisu za konvencionalno obdelavo tal za parcelo Gorica.

Table 9 Ecological footprint for conventional tillage at Gorica

Work task	Machines [ha]	Repromateria [ha]	Total [ha]
Basic tillage	0,6	/	0,6
Sowing	7	/	7
1. fertilizing	0,1	12,5	12,6
Weeding	8	/	8
Herbicide	0,1	4,3	4,4
2. fertilizing	0,1	1,5	1,6
3. fertilizing	0,1	14,7	14,8
Fungicide	0,1	1,6	1,7
Fungicide	0,1	4,1	4,2
TOTAL:	16,2	38,7	54,9

Ker so na parceli Gorica tla lahka, je odtis obdelave tal manjši kot na parceli Center. Največji odtis pusti gnojenje z gnojilom Uniko 25,5 % in znaša 14,8 ha. Najmanjši odtis pusti osnovna obdelava tal in znaša 0,6 ha, kar lahko pripisujemo tipu tal, ki omogoča večjo delovno storilnost in manjšo porabo goriva.

Konzervirajoča obdelava tal na parceli Gorica

Rezultati okoljskega odtisa za konzervirajočo obdelavo tal na parceli Gorica so razvidni iz preglednice 10.

Table 10 Ecological footprint for conservation tillage at Gorica

Work task	Machines [ha]	Repromaterial [ha]	Total [ha]
Basic tillage	21,1	/	21,1
Sowing	7	/	7
1. fertilizing	0,1	12,5	12,6
Weeding	8	/	8
Herbicide	0,1	4,3	4,4
2. fertilizing	0,1	1,5	1,6
3. fertilizing	0,1	14,7	14,8
Fungicide	0,1	1,6	1,7
Fungicide	0,1	4,1	4,2
TOTAL:	36,7	38,7	75,4

Pri konzervirajoči obdelavi tal na parceli Gorica smo najmanjši okoljski odtis zapustili z 2. dognojevanjem. Vrednost odtisa znaša 1,6 ha. Stroj za osnovno obdelavo je pustil največ odtisa in sicer 21,1 ha, kar lahko pripisujemo večji potrebni moči traktorja ter posledično večji porabi goriva med samim obdelovanjem. Na porabo goriva vpliva tudi delovna širina rahljalnika in globina rahljanja.

Neposredna setev na parceli Gorica

V preglednici 11 najdemo podatke o vrednosti okoljskega odtisa za direktno setev na parceli Gorica.

Table 11 Ecological footprint for direct sowing at Gorica

Work task	Machines [ha]	Repromaterial [ha]	Total [ha]
Sowing	7	/	7
1. fertilizing	0,1	12,5	12,6
Weeding	8	/	8
Herbicide	0,1	4,3	4,4
2. fertilizing	0,1	1,5	1,6
3. fertilizing	0,1	14,7	14,8
Fungicide	0,1	1,6	1,7
Fungicide	0,1	4,1	4,2
TOTAL:	15,6	38,7	54,3

Iz podatkov direktne setve na parceli Gorica lahko razberemo, da najmanjši odtis pusti 2. dognojevanje in sicer 1,6 ha. Največji odtis zapusti 3. dognojevanje z gnojilom Uniko 25,5 %. Skupni okoljski odtis pri direktni setvi je manjši kot pri konzervirajoči obdelavi tal, saj ne izvajamo osnovne obdelave, ampak opravljamo setev direktno v neobdelana tla.

ZAKLJUČEK

V poskusu smo primerjali okoljski odtis za tri različne načine obdelave tal na dveh različnih parcelah pri pridelavi ozimne pšenice. Proučevali smo konvencionalno in konzervirajočo obdelavo tal ter neposredno setev brez obdelave tal za dva različna poskusa na posestvu Perutnine Ptuj. Prvi poskus smo izvajali na parceli Center z ozimno pšenico 'Orvantis', kjer prevladujejo težka tla in drugega na parceli Gorica za ozimno pšenico 'Illico', kjer so tla peščena.

Ugotovili smo, da smo v obeh poskusih največ okoljskega odtisa spustili v okolje s konzervirajočo obdelavo tal. Okoljski odtis je v prvem poskusu znašal 88,1 ha in v drugem 75,4 ha. Rezultat je od ostalih načinov obdelave tal večji zaradi osnovne obdelave tal, saj ima stroj, ki smo ga uporabili v obeh poskusih, veliko porabo goriva in s tem je posledično tudi okoljski odtis večji. Poraba goriva stroja je pri poskusu 1 59 l/h in odtis, ki ga pustimo, 20,8 ha. V drugem poskusu je poraba goriva stroja 57 l/h in odtisa 21,1 ha. Končni pridelek je pri konzervirajoči obdelavi tal največji.

Najmanjši odtis v okolje smo v obeh poskusih povzročili pri neposredni setvi v neobdelana tla in je znašal na parceli Center 60,8 ha in na parceli Gorica 54,3 ha. Manjši je zato, ker pri tej obdelavi tal predhodno ne obdelujemo tal, ampak ozimno pšenico sejemo v neobdelana tla. Končni pridelek je v tem primeru najmanjši.

Gleda na to, da smo poskuse izvajali na dveh različnih tipih tal, lahko iz podatkov o okoljskem odtisu in tipu tal vidimo, da smo na težkih tleh na parceli Center pustili več okoljskega odtisa kot pa na lahkih tleh na parceli Center.

Iz dobljenih podatkov lahko sklepamo, da je optimalen način obdelave tal, glede na vrednost okoljskega odtisa in količino pridelka, konvencionalni način obdelave tal. Ta obdelava spusti v okolje srednjo vrednost okoljskega odtisa in tudi končni pridelek je zadovoljiv. Kdor hoče večji pridelek in se ne ozira na obremenitev okolje med pridelavo, se naj poslužuje konzervirajoče obdelave tal. Vendar menimo, da bi lahko v kmetijstvu začeli bolj gledati na onesnaževanje okolja in ne tako na končni pridelek in zaslužek, ter tako začeli izvajati ukrepe, s katerimi bi minimalno obremenili okolje, v našem primeru, neposredne setve brez obdelave tal.

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EFFECT OF DIFFERENT TILLAGE METHODS ON THE ECOLOGICAL FOOTPRINT OF WINTER WHEAT

PETER VINDIŠ, DENIS STAJNKO, MIRAN LAKOTA

ABSTRACT

Ecological footprint is a biologically productive land or sea area needed for satisfaction of our needs and for pollution produced in our work and activities. The aim of the research is to determine how different tillage methods affect the ecological footprint in the production of winter wheat with conventional, conservation tillage and direct sowing. The aim of the research is also to determine by using an online program which tillage method is most suitable for the production of winter wheat to reach maximum yield and minimum ecological footprint to the environment. The field experiment was carried out on two parcels with different types of soil. At both locations three different methods of soil tillage were applied. The biggest ecological footprint is caused by the conservation tillage and amounts to 88.1 ha on Center and to 75.4 ha on Gorica. The smallest footprint is caused by direct sowing and amounts to 60.8 ha on Center and to 54.3 ha on Gorica. The optimal soil tillage is the conventional tillage because of medium ecological footprint and satisfactory final yield produced.

Key words: ecological footprint / winter wheat / tillage



EKONOMIČNOST PROIZVODNJE PŠENICE I ULJANE REPICE S RAZLIČITIM SUSTAVIMA OBRADE TLA

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SAŽETAK

Pokus s pet varijanti obrade tla u proizvodnji ozime pšenice i uljane repice postavljen je na površini polju u blizini Starog Petrovog Sela (45° 10' N, 17° 30' E) u uvjetima semihumidne klime na tlu teksturne oznake praškasta ilovača. Sustavi obrade tla i primijenjena oruđa bili su: CT – plug, tanjurača, sjetvospremač, sijačica; NcT1 – rovilo, tanjurača, sjetvospremač, sijačica; NcT2 – rovilo, integrirani agregat zvrk drljača + sijačica; NcT3 – plug, integrirani agregat zvrk drljača + sijačica; NcT4 – rovilo, plug, integrirani agregat zvrk drljača + sijačica. U uzgoju ozime pšenice najveći prosječni urod od 8,79 t ha⁻¹ ostvaren je na varijanti pokusa s reduciranom obradom NcT1, dok je najviši prosječni urod uljane repice od 3,92 t ha⁻¹ zabilježen je na varijanti s intenzivnom obradom tla NcT4. Najveće uštede energije i radnog vremena u obradi tla, uz najniže ukupne troškove proizvodnje, ostvarene su na varijanti pokusa s reduciranom obradom NcT2. Najvišu ekonomičnost proizvodnje obje kulture također je polučila varijanta s reduciranim sustavom obrade NcT2 (koeficijent ekonomičnosti u proizvodnji pšenice bio je 2,54, te 1,76 kod uljane repice) te se tako pokazala najboljim sustavom proizvodnje kod obje kulture. Stoga, kod izbora sustava obrade tla, uz pretpostavku ujednačenih razina prinosa, prednost bi trebalo dati sustavu s nižom razinom agrotehnike, ne samo radi snižavanja troškova, već i zbog mogućnosti jednostavnije organizacije proizvodnje obzirom na manji utrošak radnog vremena ljudi i strojeva.

Ključne riječi: *utrošak energije, produktivnost rada, troškovi proizvodnje*

UVOD

Obrada tla ima za cilj stvoriti povoljne uvjete za klijavost sjemena i rast biljaka. Smatra se neizostavnim dijelom ratarske proizvodnje te dominira kao najveći potrošač energije.

Više od polovice utrošene energije za radove u polju otpada na obradu tla ukoliko se primjenjuje konvencionalni sustav obrade. Primjena dugogodišnje konvencionalne obrade u ratarstvu iskazala je značajne ekološke i ekonomske nedostatke. S ekološkog stajališta nedostaci konvencionalnog sustava obrade su: sustavno smanjenje sadržaja organske tvari u tlu (humusa) kao posljedica intenzivnog i učestalog djelovanja oruđa na tlo, povećanje zbijenosti tla izazvano prekomjernim gaženjem oranice strojevima, veća podložnost konvencionalno obrađenih tala eroziji (Birkás 2008). Također ekološki problem predstavlja i značajna emisija CO₂ kao posljedica izgaranja velikih količina goriva utrošenih u intenzivnoj obradi tla (Filipović et al. 2006). S ekonomskog stajališta nedostaci konvencionalnog sustava obrade tla su: veliki investicijski troškovi i troškovi održavanja mehanizacije, izrazito veliki utrošak energije i ljudsko-strojnog rada, te u konačnici veći troškovi proizvodnje ratarskih usjeva (Košutić i sur. 2006). Najbolje mogućnosti za racionalizaciju proizvodnje nudi smanjenje obrade tla, uglavnom zamjena lemešnog pluga koji zahtjeva najviše energije i vremena prilikom konvencionalnih sustava obrade tla. Prema europskim istraživanjima (Tebrügge i Düring, 1999) konvencionalni sustav obrade tla iziskuje 434 kWh ha⁻¹ energije i 4,1 h ha⁻¹ ljudsko-strojnog rada. Nasuprot tome, reduciranim sustavima obrade moguće je realizirati uštedu oko 30%-50% energije i ljudskog-strojnog rada, a izravnom sjetvom čak i do 70%, u usporedbi s konvencionalnim sustavom obrade tla.

Pšenica (*Triticum aestivum* L.) i uljana repica (*Brassica napus* L.) važni su ratarski usjevi koji su na proizvodnim površinama u Hrvatskoj uvelike zastupljeni u plodored. Dosadašnja istraživanja ukazuju da je reducirana obrada tla povoljnija za usjeve gustog sklopa poput ozime pšenice, jarog ječma i uljane repice, dok je znatno lošija opcija za jare okopavine kao što su kukuruz i soja (Vratarčić i Sudarić 2000, Pospišil i sur. 2002, Špoljar i sur. 2009, Kisić i sur. 2010). Redukcija troškova proizvodnje primjenom sustava reducirane obrade tla, u uvjetima kada zbog smanjenja razine agrotehnike nisu značajno smanjeni urodi, omogućava snižavanje praga rentabilnosti i osigurava veću razliku prinosa i prihoda za dohodak u proizvodnji (Stipešević i sur. 2007, Košutić i sur. 2008, Jug i sur. 2010). Unatoč spoznajama o mogućnostima uštede energije i ljudskog rada nekonvencionalnim načinima obrade, u Hrvatskoj je dominantan konvencionalni sustav obrade tla. U Slavoniji i Baranji, još uvijek se na većini (93,7%) oranica primjenjuje konvencionalni sustav obrade tla (Zimmer et al. 2002). Do kraja prošlog stoljeća oko 85% obradive zemlje središnje Europe je pod uobičajenim sustavima obrade tla (Stroppel, 1997). Sustavi reducirane obrade nisu se do danas bitno povećali, te se procjenjuje da još uvijek iznosi manje od 10% (ECA, 2013.). U supstituciji konvencionalnog sustava obrade tla različitim varijantama reducirane obrade i izravnom sjetvom u svijetu prednjače SAD, Kanada, Brazil, Argentina, Urugvaj, Paragvaj gdje se konzervirajuća obrada i no-till sustav primjenjuju na više od polovine ukupnih ratarskih površina (Derpsch i Friedrich, 2009). U glavnim ratarskim regijama u Hrvatskoj, Slavoniji i Baranji, još uvijek se na većini (93,7%) oranica primjenjuje konvencionalni sustav obrade tla (Zimmer et al. 2002).

MATERIJAL I METODE

Istraživanje je provedeno na pokusnom polju u sastavu proizvodnih površina poljoprivredne tvrtke „PK Nova Gradiška“ u blizini Starog Petrovog Sela (45° 10' N, 17° 30' E).

Klima na tom području je semihumidna s prosječnim godišnjim padalinama od 775 mm i prosječnom godišnjom temperaturom 10,8 °C (izvor: Državni hidrometeorološki zavod). Tlo je vertično hipoglejno (*Škorić, 1986*), a tekstura u oraničnom sloju je praškasto-glinasta ilovača (tablica 1).

Tablica 1 Veličina i distribucija čestica tla**Table 1** Soil particle size distribution

Dubina Depth (cm)	Veličina čestica / Particlesize				Teksturna oznaka Texture ¹
	0.2-2 µm (%)	0.05-0.2 µm (%)	0.002-0.05 µm (%)	<0.002 µm (%)	
0-30	16.0	28.0	22.0	34.0	SiCL ²
30-60	13.0	32.0	26.0	29.0	SiCL- SiL
60-90	13.0	31.0	28.0	28.0	SiCL

¹⁾ Prema/According to: „Soil Survey Staff of the United States Department of Agriculture“

²⁾ SiCL= Praškasto glinasta ilovača (SiltyClayLoam), SiL= Praškasta ilovača (SiltyLoam)

Pokusno polje je podijeljeno na 15 parcela s dimenzija 54x185 m postavljenih u slučajni blok raspored s tri ponavljanja za svaki sustav obrade. Sustavi obrade tla i oruđa primijenjena kod pojedinog sustava bili su:

1. Konvencionalna obrada – plug, tanjurača, sjetvospremač, sijačica (CT);
2. Reducirana obrada 1 – rovilo, tanjurača, sjetvospremač, sijačica (NcT1);
3. Reducirana obrada 2 – rovilo, integrirani agregat zvrk drljača + sijačica (NcT2);
4. Reducirana obrada 3 – plug, integrirani agregat zvrk drljača + sijačica (NcT3);
5. Kombinirana obrada – rovilo, plug, integrirani agregat zvrk drljača + sijačica (NcT4).

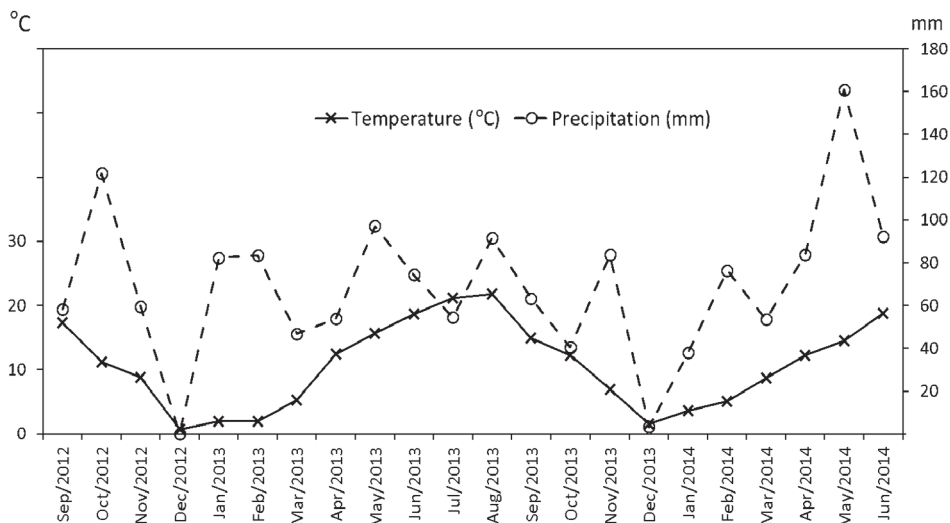
U varijantama obrade tla CT, NcT3 i NcT4 korišten je četverobrazni plug Kuhn Multimaster 151, tanjurača Kuhn Discover XM 44/660, kombinirano oruđe za predsjetvenu pripremu Lemken Korund 750L i sijačica Tive 2000. Dubinsko rahljenje u varijantama NcT1, NcT2 i NcT4 obavljeno je rovilom Agram GeoDec SVD6. U varijantama NcT2, NcT3 i NcT4 predsjetvena priprema tla i sjetva obavljene su u jednom proходу integriranim agregatom Kuhn Integra 3000 koji se sastojao od rotacijske drljače i sijačice.

Prilikom svih radnih operacija, učinak pojedinog agregata određen je kronografiranjem. Utrošak energije određen je mjerenjem utroška goriva volumetrijskom metodom za svako oruđe u svakom od uspoređivanih sustava obrade, te potom izračunat na osnovi energetskog ekvivalenta diesel goriva. Radni zahvati pojedinih oruđa odabrani su na osnovi raspoložive vučne snage traktora. Ukupni urod pojedinog usjeva sa svake obračunske parcele izmjeren vaganjem elektronskim vagama izravno na polju. Vlažnost zrna u vrijeme žetve određivana je naknadno u laboratoriju, te je osnovom toga urod preračunat na površinu od jednog hektara i skladišnu vlagu promatranog usjeva. Raspored radova u polju kao i primijenjene doze gnojiva i zaštitnih sredstava prikazani su u tablici 2.

Tablica 2 Raspored radova i primijenjene doze
Table 2 Date of field operations and application rates

Opis / Description	Pšenica / Winter Wheat	Uljana repica / Oil Seed Rape
Obrada tla i sjetva / Tillage & Sowing		
Osnovna obrada / Primary tillage	7. kolovoz 2012. August 7 th 2012	30. srpanj 2013. July 7 th 2013
Dopunska obrada / Secondary till.	29. rujan 2012. September 29 th 2012	3. rujan 2013. September 3 rd 2013
Datum sjetve / Sowing date	10. listopada 2012. October 10 th 2012	3. rujan 2013. September 3 rd 2013
Kultivar (kg ha ⁻¹) Cultivar (kg ha ⁻¹)	Apache C1 (220)	Extrom (2,9)
Gnojidba / Fertilizing		
Vrijeme primjene / Appl. date	29. rujan 2012. September 29 th 2012	22. kolovoz 2013. August 22 nd 2013
Gnojivo, doza (kg ha ⁻¹) Fertilizer, rate (kg ha ⁻¹)	NPK 8:26:26 (400)	MAP 12:52 (200) KCl 60 % (100)
Vrijeme primjene / Appl. date	13. veljače 2013. February 13 th 2013	18. veljače 2014. February 18 th 2014
Gnojivo, doza (kg ha ⁻¹) Fertilizer, rate (kg ha ⁻¹)	KAN 27% (120)	KAN 27% (250)
Vrijeme primjene / Appl. date	28. svibanj 2013. March 28 th 2013	15. ožujak 2014. March 15 th 2014
Gnojivo, doza (kg ha ⁻¹) Fertilizer, rate (kg ha ⁻¹)	urea 46% (100)	urea 46% (300)
Zaštita / Crop protection		
Vrijeme primjene / Appl. date	26. rujan 2012. September 26 th 2012	3. rujan 2013. September 3 rd 2013
Sredstvo, doza (l ha ⁻¹) Chemical, rate (l ha ⁻¹)	glyphosat (2,0)	metazaklor+klomazon (1,9+0,2)
Vrijeme primjene / Appl. date	12. svibanj 2013. May 12 th 2013	20. listopada 2013. October 20 th 2013
Sredstvo, doza (l ha ⁻¹) Chemical, rate (l ha ⁻¹)	ciprokonazol+propi-konazol (0,5) metiltiofanat+epoksi-konazol (0,5)	quizalifop p tefuril (1,0)
Vrijeme primjene / Appl. date	2. lipanj 2013. June 2 th 2013	21. ožujak 2014. March 21 st 2014
Sredstvo, doza (l ha ⁻¹) Chemical, rate (l ha ⁻¹)	alfacipermetrin (0,1) ciprokonazol+propi-konazol (0,5)	klorpirifos+cipermetrin (0,9)
Vrijeme primjene / Appl. date		7. travanj 2014. / April 7 th 2014
Sredstvo, doza (l ha ⁻¹) Chemical, rate (l ha ⁻¹)		boskalida+dimoksistrobin (0,5)
Žetva / Harvest		
Datum žetve / Harvesting date	18. srpanj 2013. / July 18 th 2013	1. srpanj 2014. / July 1 st 2014

Klimatski uvjeti tokom provedbe pokusa bili su povoljni za uzgoj pšenice u uljane repice. Srednje mjesečne temperature zraka odgovarale su višegodišnjim prosjecima, uz dovoljne količine oborima tokom sezone vegetacije što je vidljivo iz klimadijagrama prema Walteru (slika 1).



Slika 1 Klimadijagram prema Walteru za razdoblje uzgoja ozime pšenice i uljane repice
Figure 1 Walter climate diagram for soybean and barley cropping period

Ekonomska učinkovitost izračunata je osnovom naturalnih pokazatelja proizvodnje pšenice i uljane repice (utrošci rada, materijala, prinosi), te cijena inputa i outputa proizvodnje.

Statistička obrada podataka za sve pokazatelje istraživanja učinjena je računalnim programom SAS (SAS Institute, 1990) metodom analize varijance (ANOVA). Značajnost razlika između promatranih pokazatelja utvrđena je F-testom na razini vjerojatnosti $p=0.05$.

REZULTATI I RASPRAVA

Urod

U uzgoju ozime pšenice najviši prosječni urod od $8,79 \text{ t ha}^{-1}$ ostvaren je na varijanti pokusa s reduciranom obradom NcT1 što je za 12 % više od konvencionalnog sustava s $7,83 \text{ t ha}^{-1}$ što je ujedno bio i najniži prosječni urod. Analizom varijance utvrđena je statistički značajna ($p<0,05$) razlika uroda koji je kod svih nekonvencionalnih sustava bio viši u odnosu na konvencionalnu obradu tla (tablica 3).

Obzirom na urod uljane repice najboljim izborom pokazala se varijanta pokusa s intenzivnom obradom tla NcT4 gdje je ostvaren prosječni urod od $3,92 \text{ t ha}^{-1}$, što je za 1 % više od uroda dobivenog konvencionalnim sustavom ($3,87 \text{ t ha}^{-1}$). Na varijantama pokusa s reduciranom obradom prosječni urodi bili su statistički značajno niži i to na NcT1 9 %, NcT2 7 % i na NcT3 13 % manji urod u odnosu na konvencionalni sustav.

Tablica 3 Utrošak energije, učinak i produktivnost različitih načina obrade tla
Table 3 Energy and labour requirement of different soil tillage systems

	Pšenica / Winter Wheat				Uljana repica / Oil Seed Rape			
Obrada Tillage system	Gorivo Fuel l ha ⁻¹	Energija Energy MJ t ⁻¹	Produktivnost Productivity h ha ⁻¹ h t ⁻¹		Gorivo Fuel l ha ⁻¹	Energija Energy MJ t ⁻¹	Produktivnost Productivity h ha ⁻¹ h t ⁻¹	
CT	Urod / Average yield = 7,83t ha ⁻¹ b ⁽¹⁾				Urod / Average yield = 3,87t ha ⁻¹ a			
Plug / Plough	30,05	148,5	0,97	0,13	24,23	242,1	1,30	0,34
Tanjurača Disc harrow	9,89	48,9	0,31	0,04	9,76	97,5	0,33	0,09
Sjetvospremač Seed-bed impl.	4,96	24,5	0,24	0,03	5,86	58,6	0,17	0,04
Sijačica / Drill	3,43	17,0	0,19	0,02	2,85	28,5	0,25	0,06
Ukupno / Total	48,33	238,9	1,71	0,22	42,7	426,7	2,05	0,53
NcT1	Urod / Average yield = 8,79t ha ⁻¹ a				Urod / Average yield = 3,53t ha ⁻¹ b			
Rovilo / Chisel	14,97	65,9	0,66	0,07	17,07	187,3	0,53	0,15
Tanjurača Disc harrow	9,89	43,5	0,31	0,04	9,76	107,1	0,33	0,09
Sjetvospremač Seed-bed impl.	4,96	21,8	0,24	0,03	5,86	64,3	0,17	0,05
Sijačica / Drill	3,43	15,1	0,19	0,02	2,85	31,3	0,25	0,07
Ukupno / Total	33,25	146,3	1,40	0,16	35,54	390,0	1,28	0,36
NcT2	Urod / Average yield = 8,54t ha ⁻¹ a				Urod / Average yield = 3,61 t ha ⁻¹ b			
Rovilo / Chisel	14,97	67,8	0,66	0,08	17,07	183,1	0,53	0,15
Integra / Rotary harrow + drill	13,69	62,0	0,65	0,07	15,38	165,0	0,71	0,20
Ukupno / Total	28,66	129,8	1,31	0,15	32,45	348,1	1,27	0,35
NcT3	Urod / Average yield = 8,71t ha ⁻¹ a				Urod / Average yield = 3,36 t ha ⁻¹ b			
Plug / Plough	30,05	133,5	0,97	0,12	24,23	279,0	1,30	0,39
Integra / Rotary harrow + drill	13,69	60,8	0,65	0,07	11,99	138,1	0,59	0,17
Ukupno / Total	43,74	194,3	1,62	0,19	36,22	417,1	1,89	0,56
NcT4	Urod / Average yield = 8,76t ha ⁻¹ a				Urod / Average yield = 3,92 t ha ⁻¹ a			
Rovilo / Chisel	14,97	66,1	0,66	0,08	17,07	168,4	0,53	0,13
Plug / Plough	30,05	132,7	0,97	0,11	24,23	239,1	1,30	0,33
Integra / Rotary harrow + drill	13,69	60,5	0,65	0,07	11,99	118,3	0,58	0,15
Ukupno / Total	58,71	259,3	2,28	0,26	53,29	525,8	2,41	0,61

⁽¹⁾Različita slova ukazuju na statistički značajne razlike na razini vjerojatnosti p ≤ 0.05

Different letters indicate significant (p ≤ 0.05) differences

Energija i učinak

Konvencionalni sustav obrade tla očekivano se pokazao zahtjevnim s gledišta utroška energije i radnog vremena. Ukupno je u obradi tla i sjetvi ozime pšenice konvencionalnim sustavom utrošeno 48,33 l ha⁻¹ diesel goriva pri čemu se oranje lemešnim plugom ističe kao najznačajniji potrošač s oko 62 % ukupno utrošene energije. Najviše goriva/energije (58,71 l ha⁻¹) u obradi tla utrošeno je u varijanti pokusa NcT4 gdje je zabilježen i najviši specifični utrošak energije od 259,3 MJ t⁻¹ po toni prinosa odnosno 9 % više u odnosu na varijantu s konvencionalnim sustavom obrade (238,9 MJ t⁻¹). U varijantama pokusa s reduciranom obradom tla NcT1 i NcT2 utrošeno je za trećinu manje goriva/energije pri čemu se sustav NcT2 ističe s 45,7 % manjim specifičnim utroškom energije (129,8 MJ t⁻¹) u odnosu na konvencionalni sustav. Osim po utrošku energije kombinirani sustav obrade tla NcT4 pokazao se najzahtjevniji i obzirom na utrošak radnog vremena pa je tako za obradu i sjetvu jednog hektara utrošeno 2,28 sati rada strojeva odnosno gledano obzirom na ostvareni prinos zrna pšenice 0,26 sati po toni prinosa. U varijanti pokusa s konvencionalnim sustavom obrade tla utrošeno je 1,71 h ha⁻¹ odnosno 0,22 h t⁻¹. U varijantama pokusa s reduciranom obradom tla NcT1 i NcT2 ostvarene su uštede radnog vremena preko 20%, pri čemu su i učinci po jedinici prinosa pšenice bili za 30 % veći.

U proizvodnji uljane repice najviše je goriva/energije utrošeno u sustavu obrade NcT4 (53,29 l ha⁻¹) uz specifični utrošak od 525,8 MJ t⁻¹, dok je za konvencionalnu obradu utrošeno 42,7 l ha⁻¹ odnosno 426,7 MJ t⁻¹ pri čemu je za oranje utrošeno 57 % ukupnog iznosa. Primjenom reduciranih sustava obrade tla ponovo su ostvarene znatne uštede energije. Najpovoljnija varijanta, obzirom na utrošenu energiju, pokazala se NcT2 s potrošnjom goriva od 32,45 l ha⁻¹ i s utrošenom energijom od 348,1 MJ t⁻¹. Također je i utrošak radnog vremena u obradi tla na varijantama pokusa s reduciranom obradom tla bio znatno manji u odnosu na konvencionalnu obradu, a najveća ušteda od 33,9 % ostvarena je u sustavu NcT2 gdje je u obradi ukupno utrošeno 0,35 h t⁻¹.

Uspoređujući dobivene rezultate s navodima drugih autora (*Pelizzi i sur. 1988; Hernanz i Ortiz-Cañavate 1999; Kovačev i sur. 2014*) mogu se očekivati veća odstupanja obzirom na tipove tala, trenutne uvjete u polju, dubinu obrade i korištena oruđa, no uočljivo je povećanje produktivnosti rada sa stupnjem redukcije obrade tla.

Ekonomičnost proizvodnje

Ukupni prihodi u proizvodnji ozime pšenice i uljane repice izračunati su prema prosječnom prinosu sa svake varijante pokusa i prosječnoj otkupnoj cijeni u vrijeme žetve, te državnim poticajima. Ukupni troškovi uključuju sve troškove mehanizacije od obrade tla do žetve (uključivo transport u polju), repromaterijal (sjeme, gnojiva, zaštitna sredstva), i ljudski rad. Skladištenje uroda i režijski troškovi poljoprivredne tvrtke ovdje nisu uračunati.

U proizvodnji ozime pšenice najveći prihod, kao rezultat najviših uroda, ostvaren je na varijanti pokusa s reduciranom obradom tla NcT1, međutim najviši koeficijent ekonomičnosti (omjer prihoda i troškova) zabilježen je u sustavu NcT2 prvenstveno zbog najmanjih troškova proizvodnje (tablica 4). Najveće troškove proizvodnje generirao je konvencionalni sustav obrade tla, ponajviše zbog velikog broja radnih operacija i utroška vremena, što je s najnižim ostvarenim prosječnim urodom rezultiralo i najnižim koeficijentom ekonomičnosti od 2,11.

U proizvodnji uljane repice najviši prihodi ostvareni su u varijantama pokusa s intenzivnom obradom tla NcT4 i konvencionalnim sustavom. Iako su u svim varijantama s reduciranim sustavima obrade urodi, a time i prihodi, bili značajno niži, varijanta NcT2 pokazala se kao najekonomičnija zbog najnižih troškova proizvodnje s koeficijentom 1,76, dok su varijante NcT1 i NcT3 bile lošije od konvencionalnog sustava.

Tablica 4 Ekonomski pokazatelji proizvodnje soje i ječma
Table 4 Economic efficiency indicators of winter wheat and rapeseed production

Obrada Tillage	Pšenica / Winter Wheat			Uljana repica /Oil Seed Rape		
	Ukupni prihod Gross inc. € ha ⁻¹	Ukupni troškovi Total costs € ha ⁻¹	Omjer prihodi/troškovi Income/Costs ratio	Ukupni prihod Gross inc. € ha ⁻¹	Ukupni troškovi Total costs € ha ⁻¹	Omjer prihodi/troškovi Income/Costs ratio
CT	1.659,00	787,00	2,11	1.499,00	886,00	1,69
NcT1	1.837,00	734,00	2,50	1.392,00	834,00	1,67
NcT2	1.791,00	704,00	2,54	1.416,00	804,00	1,76
NcT3	1.822,00	757,00	2,41	1.340,00	856,00	1,57
NcT4	1.831,00	778,00	2,35	1.515,00	900,00	1,68

ZAKLJUČCI

Temeljem provedenih istraživanja utjecaja nekonvencionalnih sustava obrade na ekonomičnost proizvodnje, te prikazanih rezultata, može se zaključiti da je proizvodnja ozime pšenice i uljane repice bila ekonomična u svim varijantama obrade tla. Bolji ekonomski rezultati u proizvodnji pšenice postignuti su na varijantama s reduciranim sustavima obrade, što je rezultat visokih prinosa i smanjenja troškova proizvodnje u usporedbi s konvencionalnim sustavom, te je najviši koeficijent ekonomičnosti od 2,54 ostvaren u varijanti NcT2. Urodi uljane repice u svim varijantama pokusa s reduciranom obradom tla bili su niži u odnosu na varijante CT i NcT4, dakle uz intenzivnu obradu, te je jedino na NcT2 ekonomičnost proizvodnje bila viša od konvencionalnog sustava, isključivo zbog najnižih troškova proizvodnje.

Najveće uštede energije po toni prinosa omogućio je NcT2 sustav, 45,7% kod proizvodnje ozime pšenice i 45,6% kod uljane repice, u odnosu na konvencionalni sustav obrade tla. Najviša produktivnost rada također je ostvarena NcT2 sustavom obrade, te se zbog najbolje ekonomske učinkovitosti ovaj sustav obrade tla može se preporučiti za proizvodnju proučavanih kultura.

Slijedom navedenog proizlazi da je redukcijom obrade tla moguće ostvariti znatne uštede energije i radnog vremena ljudi i strojeva. Stoga bi kod izbora sustava obrade tla, uz pretpostavku ujednačenih razina prinosa, prednost trebalo dati sustavu s nižom razinom agrotehnike, ne samo radi snižavanja troškova, već i zbog mogućnosti jednostavnije organizacije proizvodnje.

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ECONOMIC EFFICIENCY OF WINTER WHEAT AND OIL SEED RAPE PRODUCTION IN DIFFERENT SOIL TILLAGE SYSTEMS

SUMMARY

*Short-term study of non-conventional soil tillage systems was conducted at the experimental field near Štivica (45° 09' N, 17° 31' E) on hypogley-vertic type of soil and semi humid climate conditions. Winter wheat (*Triticum aestivum* L.) and oil seed rape (*Brassica napus* L) were cultivated on five soil tillage systems. The tillage systems and implements used were: CT – mouldboard plough, disc harrow, multitiller, drill, NcT1 – chisel plough, disc harrow, multitiller, drill, NcT2 – chisel plough, rotary harrow integrated with seed drill, NcT3 – mouldboard plough, rotary harrow integrated with seed drill, NcT4 – chisel plough, mouldboard plough, rotary harrow integrated with seed drill. The highest average yields were obtained by NcT1 system in winter wheat (8.79 t ha⁻¹) and NcT4 in rapeseed production (3.92 t ha⁻¹), while the highest economic efficiency for both crops was gained with NcT2 system (coefficient of 2.54 for wheat and 1.76 for rapeseed). The greatest energy and labour savings in soil tillage, among the lowest total cost of production, were also achieved by NcT2 system. Therefore, regarding the choice of tillage systems, assuming uniform level of yields, the advantage should be given to systems with lower level of tillage intensity, not only to reduce costs but also because of the possibility of simpler production organization due to less machine and labour requirement.*

Key words: energy consumption, labour productivity, production costs



INFLUENCE OF A JET'S ANGLE SIZE ON THE SPRAYING PROCESS

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SUMMARY

Within the spraying process, the compact jet of solution which comes out from a limited space, represented by the nozzle's body or sprayer, is transformed in a jet of droplets, through liquid dispersion in space, under a certain angle, at a speed capable to surpass the liquid's forces of internal cohesion. The spraying angle of the jet is the cone's angle formed between the tangents to the jet's contour, concurrent in the nozzle's orifice. The spraying angle, as also the jet penetration, illustrates the liquid's distribution on the surface to spray. This angle depends in a great measure of the nozzle type and its orifice size. The pressure of the liquid has a significant effect on the size of the spraying angle. Within the paper is presented a mathematic model which characterizes the angle of the nozzle's jet for spraying machines in field crops in function of the working process parameters. This model is then experimentally validated through on stand tests which simulate the real working conditions.

Key words: spraying machines, nozzle's jet angle, nozzle, phyto-sanitary treatments

INTRODUCTION

Nowadays realities show that the XX-th century is the period of greatest discoveries and transformations of the humane civilization as also of the most complex and unthinkable effects on life.

Agriculture's productivity is influenced by the level of applied work technologies, the phyto-sanitary protection occupying a very important place within these technologies. Actual studies and researches regarding methods and equipment for application of phyto-sanitary treatments are framed within the new tendencies for practicing a sustainable

agriculture, being a known fact that the phyto-sanitary protection represents one of the main sources of reduction of environment pollution with chemicals [1].

An important aspect of continuum increasing politics of product quality promoted by each manufacturer is represented by both maintaining plants protection machines conformity as also increasing of premises of manufacturing in conditions of repeatability of those products.

The purpose of a spraying work is to deposit uniformly a maximum quantity of phyto-sanitary products in the right place (target), respectively on the sprayed surface [6, 7].

For the spraying machine in field crops, which generally has as main component parts: tank, stirrer, pump, valves, distributor, spraying ramp, one of the most important part is represented by the nozzles [2, 8], which influence directly the quality of the spraying process.

Spraying represents the decomposition process of a liquid jet in droplets. By spraying it's dispersed the liquid in small diameter droplets, although the medium diameter of the resulted droplets could be very different, from a few microns (μm) until $2\div 3$ mm.

The spraying process of the liquid's jet has been studied by numerous researchers, the obtained results allowing to conclude that the jet's surface which comes out from the orifice of a nozzle is subjected to small perturbations. These small perturbations are created by the following factors: flowing process of the liquid, friction forces, small size of the nozzle's orifice and its imperfect round shape, presence in the jet stream of air bubbles, mechanical impurities, etc.

Within the paper we proposed a model which establishes how the spraying angle of the nozzle's jet influences the spraying process and implicitly the working process of the spraying machine, by applying dimensional analysis [5] and similitude theory.

MATERIAL AND METHODS

Application of spraying solutions by spraying with small diameter size droplets, which to cover the sprayed surface with a fine film of phyto-sanitary product, has conducted to considerable reducing of the amount of water necessary for solutions preparation and of active substance losses by dripping from the treated vegetal materiel.

The spraying angle is the cone's jet angle and indicates how wide it is. The size of the spraying angle is dependent of the liquid's density and is a measure of the tangential and axial components of the droplet's speed [3].

The spraying angle depends in great measure of the type and size of the nozzle's orifice. Also the pressure of the liquid has a significant effect on the size of the spraying angle. In practice the nozzle has marked on it also the geometric spraying angle.



Fig. 1 Liquid spraying [7]

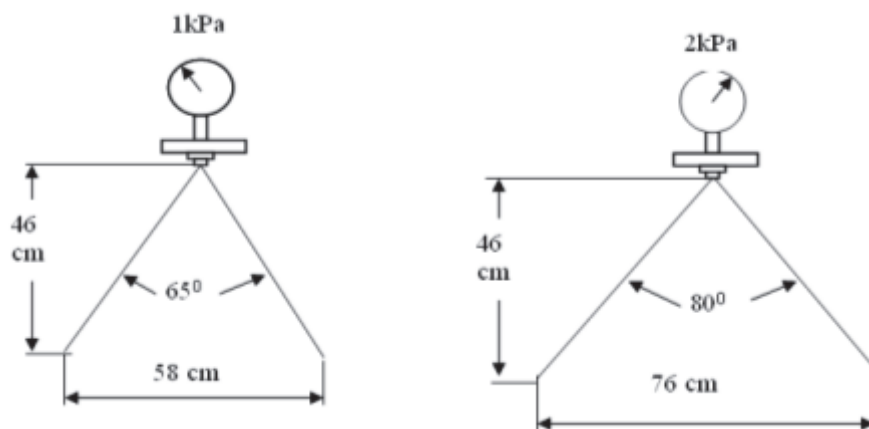


Fig. 2 Decreasing of the spraying angle once with the drop in pressure [3]

Generally the liquids more viscous than water form smaller spraying angles, while liquids with superficial tension lower than the water are dispersed at wider angles. A drop of the spraying angle with 2...10% conducts to a non-uniformity of distribution on the length of the spraying lance.

Also, modifying the superficial tension conducts to modify the size of droplets as also the spraying angle.

Most favourable situation of jet decomposition is for the ratio:

$$\frac{\lambda}{d_c} = 4,42 \quad (1)$$

where:

λ – wavelength of oscillation

d_c – jet diameter.

Study of liquid mesh decomposition could be done by using the method of the smallest perturbations, method of probable hypothesis and by dimensional analysis method.

For establishing the physical relations one could use the dimensional analysis. This method is based on the fundamental theory of dimensional analysis, Π theorem, of Vaschy-Buckingham. According to this theorem, the physiscal or physical-chemical proceses can be described through functions of independent similitude criterias which could be formed with variables which control the process. It is considered that are independent those criteria which cannot be described by arithmetic combinations of those criteria.

Thus, if a process is determined by n dimensional variables: $X_1, X_2, X_3... X_n$, this could be described by a criteria function of general form:

$$F(\Pi_1, \Pi_2, \Pi_3... \Pi_{n-m}) = 0 \quad (2)$$

Dimensional analysis represents the study of relations which describe the physical phenomena. It is based on the property of dimensional homogeneity which has to be respected by the theory of rational relations as also by the empiric ones. This property refers to the fact that the terms of a physical relation have to be homogenous, which means to have the same measuring units as also the same powers of the fundamental measures [4].

General dimensional analysis is connected with cases which, in restrained dimensional analysis conduct to equation systems between exponents of dimension and exponents of undetermined measure.

RESULTS AND DISCUSSION

Applying Π theorem (number of independent criteria from the criteria function is given by the difference $n-r$, where n is the dimensional variable number and r is the dimensional matrix rank, which is equal with the number of fundamental measures in function of which we can describe the variables taken into analysis)[5], we can write the next function of $m^* = 8$ variables:

$$f(D, v, \rho_l, \alpha, \eta_l, p, \rho_g, \sigma) = 0 \quad (3)$$

where:

D – nozzle diameter

v – relative speed of liquid towards the surrounding gas

ρ_l – liquid density

α – jet's angle

η_l – dynamic viscosity of liquid

p – liquid's pressure

ρ_g – gas density

σ – liquid's superficial tension

and D , v , ρ_l have been chosen as fundamental measures.

We have introduced the next non-dimensional complexes ($\Pi_1, \Pi_2, \Pi_3, \Pi_4, \Pi_5$):

$$\Pi_1 = \alpha; \Pi_2 = \frac{\eta_l}{D^{x_1} v^{x_2} \rho_l^{x_3}}; \Pi_3 = \frac{p}{D^{x_1} v^{x_2} \rho_l^{x_3}}; \Pi_4 = \frac{\rho_g}{\rho_l}; \Pi_5 = \frac{\sigma}{D^{x_1} v^{x_2} \rho_l^{x_3}} \quad (4)$$

The dimensional matrix of the variables for the 3 fundamental measures is presented in the next relation:

	x_1''	x_2''	x_3''					
	x_1'	x_2'	x_3'					
	x_1	x_2	x_3					
	D	v	ρ_l	α	η_l	p	ρ_g	σ
L	1	1	-3	0	-1	-1	-3	1
M	0	0	1	0	1	1	1	1
T	0	-1	0	0	-1	-2	0	-2

(5)

From the matrix we extract the linear dimensional equations system which respects the homogeneity condition for non-dimensional complex Π_2 :

$$\begin{aligned} (L) \quad & x_1 + x_2 - 3x_3 = -1 \\ (M) \quad & x_3 = 1 \\ (T) \quad & -x_2 = -1 \end{aligned} \quad (6)$$

We obtained the following solutions $x_1 = 1$; $x_2 = 1$; $x_3 = 1$ and results:

$$\Pi_2 = \frac{\eta_l}{Dv\rho_l} \quad (7)$$

The linear dimensional equations system which respects the homogeneity condition for non-dimensional complex Π_3 is:

$$\begin{aligned}
 \text{(L)} \quad x_1' + x_2' - 3x_3' &= -1 \\
 \text{(M)} \quad x_3' &= 1 \\
 \text{(T)} \quad -x_2' &= -2
 \end{aligned} \tag{8}$$

We obtained the following solutions $x_1' = 0$; $x_2' = 2$; $x_3' = 1$ and resulted:

$$\Pi_3 = \frac{p}{v^2 \rho_l} \tag{9}$$

The linear dimensional equations system which respects the homogeneity condition for nondimensional complex Π_5 is:

$$\begin{aligned}
 \text{(L)} \quad x_1'' + x_2'' - 3x_3'' &= 0 \\
 \text{(M)} \quad x_3'' &= 1 \\
 \text{(T)} \quad -x_2'' &= -2
 \end{aligned} \tag{10}$$

We obtained the following solutions $x_1'' = 1$; $x_2'' = 2$; $x_3'' = 1$ and resulted:

$$\Pi_5 = \frac{\sigma}{Dv^2 \rho_l} \tag{11}$$

So that:

$$\varphi_1(\Pi_1, \Pi_2, \Pi_3, \Pi_4, \Pi_5) = 0$$

or

$$\Pi_1 = \varphi_1(\Pi_2, \Pi_3, \Pi_4, \Pi_5) \quad (*) \tag{12}$$

which means:

$$\alpha = \varphi_2\left(\frac{\eta_l}{Dv\rho_l}, \frac{p}{v^2\rho_l}, \frac{\rho_g}{\rho_l}, \frac{\sigma}{Dv^2\rho_l}\right) \tag{13}$$

Non-dimensional complex Π_1 :

$$\Pi_1 = k\Pi_2^a\Pi_3^b\Pi_4^c\Pi_5^d \tag{14}$$

We made combinations between non-dimensional complexes, so that to appear a physical measure easy to vary in a single complex, in our case v . Thus, we combined non-

dimensional complexes Π_2, Π_3 and Π_5 , which to eliminate v and we got the new complexes Π'_2, Π'_3 and Π'_5 :

$$\Pi'_2 = \frac{\Pi_2^2}{\Pi_5} = \frac{\eta_l^2}{D^2 v^2 \rho_l^2} \cdot \frac{D v^2 \rho_l}{\sigma} = \frac{\eta_l^2}{D \rho_l \sigma} \quad (15)$$

$$\Pi'_3 = \frac{\Pi_3}{\Pi_5} = \frac{p}{v^2 \rho_l} \cdot \frac{D v^2 \rho_l}{\sigma} = \frac{p D}{\sigma} \quad (16)$$

$$\Pi'_5 = \frac{\Pi_5}{\Pi_3} = \frac{\sigma}{D v^2 \rho_l} \cdot \frac{v^2 \rho_l}{p} = \frac{\sigma}{p D} = \frac{1}{\Pi_3} \quad (17)$$

Relation (*) (13) became:

$$\Pi_1 = k_1 \Pi_2'^a \Pi_3'^b \Pi_4^c \Pi_5'^d \quad (18)$$

but:

$$\Pi_4 = \frac{\rho_a}{\rho_l} = \text{const.} \Rightarrow k_1 \left(\frac{\rho_a}{\rho_l} \right)^c = k \quad (19)$$

so:

$$\Pi_1 = k \Pi_2'^a \Pi_3'^b \Pi_5'^d = k \Pi_2'^a \Pi_3'^b \left(\frac{1}{\Pi_3'} \right)^{-d} = k \Pi_2'^a \Pi_3'^{b-d} \quad (20)$$

We noted: $b-d = e = \text{ct.}$ and it resulted:

$$\Pi_1 = k \Pi_2'^a \Pi_3'^e \quad (21)$$

which means:

$$\alpha = k \left(\frac{\eta_l^2 \sigma}{D \rho_l} \right)^a \cdot \left(\frac{p D}{\sigma} \right)^e \quad (22)$$

Making the hypothesis that the used liquid is water, the values of the following parameters η_l, σ, ρ_l , could be considered constant, so that the size of the jet's angle will

only depend on the working pressure and the nozzle's diameter, according to the following relation:

$$\alpha = kp^xD^y \quad (23)$$

For validating the theoretical model we used a testing stand fitted with pressure manometer, two nozzle holders and a marked angle pattern for direct measuring of the jet's angle. This stand allowed us to vary the working pressure and also the type of used nozzle, simultaneously with the angle measurement by the photometric method.



Fig. 3 Nozzle's jet angle testing stand

In table 1 we presented the experimental results obtained after testing three types of nozzles, at five levels of working pressure, recording for each situation the jet's angle.

Table 1 Jet angle variation

Nr. Crt	Nozzle geometry [angle (°)/ diameter, [mm]]	Jet's angle $\alpha(^{\circ})$	Pressure (bar)				
			1	2	3	4	5
1	120/0.1		90	100	110	120	130
2	120/0.25		100	110	120	130	140
3	120/0.6		110	120	130	140	150

At the highest working pressure used, of 5 bar and for the nozzle with the biggest diameter, 0.6 mm, we recorded the highest span of the observed angle, 150°. This rule is valid also for the minimal values used, 1 bar, 0.1 mm and 90°.

After interpolation of experimental data by the least squares method we obtained the following values for k , x , and y , constants from relation (23):

$$k = 3.736$$

$$x = 0.207$$

$$y = 0.095$$

So that:

$$\alpha = 3.736p^{0.207}D^{0.095} \quad (24)$$

In figure 4 we presented graphically the spraying jet angle evolution in function of the working pressure and of the nozzle's dimensional characteristics, obtained after application of model presented in relation (24). We can observe that the evolution is placed in the 3-D space, the final form of the jet's angle being a function of two variables. Using this graph is easy to understand how the jet's angle shifts values in correlation with the two input parameters.

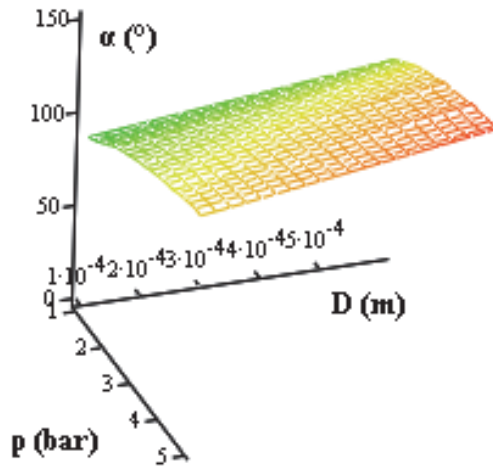


Fig. 4 Jet's angle evolution in function of the two variables: working pressure and nozzle's diameter

In table 2 we presented a comparative situation between the measured values for the jet's angle and the calculated values using the obtained mathematical model.

Table 2 Jet's angle α : comparative study

$\alpha_{\text{measured}} (^{\circ})$	90	100	110	120	130	140	150
$\alpha_{\text{calculated}} (^{\circ})$	89.516	103.324	112.368	119.261	130.067	136.214	147.983

As we can observe the registered errors between the proposed mathematical model and the experimentally obtained data are fewer than 5%, which in modelling terms is a very good ratio.

CONCLUSIONS

The variation of the spraying jet's angle for the field crop spraying machines represents a parameter directly responsible for the quality of phyto-sanitary treatment application.

The proposed theoretical model using the restrained similitude theory has identified as main variables which influence the jet's angle size the working pressure and the nozzle's diameter, presuming that the used fluid has constant physical properties. Also we presumed that the geometrical nozzle's angle is constant.

The obtained experimental results were used for determination of the model's constants and finally for its validation. In order to reduce the errors between the calculated values using the proposed model and the actual measured values, we propose to enhance the model through introducing a new variable which characterizes geometrically a nozzle: its constructive angle.

The degree of plants coverage with phyto-sanitary substance is directly influenced by the nozzle's jet angle. For obtaining values optimal for this degree it's imposed to understand the evolution of the jet's angle in function of the working parameters. Our proposed model, after being validated through experimental data could be an important tool for achieving this desiderate.

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ISPITIVANJE STROJEVA I OPREME U ZAŠTITI BILJA U REPUBLICI HRVATSKOJ

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SAŽETAK

Ulaskom u EU Republika Hrvatska preuzela je obavezu primjene direktive 2009/128/EC i 2006/42/EC koja propisuje obavezni pregled tehničkih sustava u zaštiti bilja (raspršivači i ratarske prskalice). Navedena direktiva uvedena je u Zakon o održivoj uporabi pesticida (NN 14/14), prema kojem svi uređaji pri zaštiti bilja do studenog 2016. moraju nositi naljepnicu o redovitom tehničkom pregledu, a uređaji koji su proizvedeni prije 1995. godine moraju biti pregledani najkasnije do studenoga 2014. godine. Zbog navedene problematike i približavanja rokova navedene direktive i zakon postaju aktualne te im se treba pridavati dodatnog značaja. U radu je prikazana metodika obavljanja tehničkog pregleda uz korištenu opremu, te je prikazan dio pregledanih strojeva (cca. 500) u Republici Hrvatskoj (ispitna stanica 001 i 004). Od ukupno testiranih strojeva njih 75,40% zadovoljava standarde s obzirom na kapacitet crpke; 54,00% s obzirom na ispravnost manometra i 69,20% s obzirom na površinsku raspodjelu tekućine.

Ključne riječi: raspršivač, prskalice, mlaznica, EN 13790 standard, testiranje

UVOD

Obavezna provjera tehničkih sustava u zaštiti bilja na prostorima Europske unije započela su krajem devedesetih godina prošlog stoljeća, a provjere u pojedinim članicama na dobrovoljnoj osnovi datiraju iz ranih osamdesetih godina prošlog stoljeća. Donošenjem "Zakona o održivoj uporabi pesticida" (NN 14/14) pravno su bili zadovoljeni svi uvjeti da se i službeno započne s provjerom tehničkih sustava u zaštiti bilja u Republici Hrvatskoj. Tako je je u travnju 2014. godine zabilježeno prvo službeno testiranje u Republici Hrvatskoj koje je obavila "Ispitna stanica 001 Zavoda za mehanizaciju Poljoprivrednog

fakulteta u Osijeku“ koja je, ujedno, prva ovlaštena ispitna stanica u Republici Hrvatskoj. Navedeno testiranje obavljeno je u vinariji “Krauthaker“ d.o.o. Kutjevo. U ovom trenutku u Republici Hrvatskoj kontrolu tehničke ispravnosti tehničkih sustava u zaštiti bilja provodi šest ovlaštenih ispitnih stanica koje su do današnjeg dana provjerile između 3000 i 3500 strojeva. Testiranjem na području Njemačke utvrđeno je da su neispravne mlaznice najveći uzrok neispravnosti tehničkih sustava. Testiranjem više od 70000 prskalica, prema navodima Reitz i Gamzlemeiera (1998.), kod 19% istraživanog broja strojeva utvrđena je neispravnost mlaznica. U Belgiji u razdoblju od 1995. do 1998. godine, prema navodima Langenkens i Pietersa (1999.), testiranje 17466 prskalica pokazalo je da 86% ima neispravan tlakomjer (manometar) i mlaznice. Wehmann, H. (2009) navodi da je u Austriji do 2008. godine pregledano 19875 strojeva za zaštitu bilja; u Njemačkoj 145896; u Poljskoj 102406 te u Norveškoj 2950 strojeva. Polveche, V. (2012.) navodi da je u Francuskoj pregledano 40% od ukupnog broja strojeva za zaštitu bilja koji su u eksploataciji, dok Bondesan, D. i sur. (2012) navode da se u talijanskoj pokrajini Trento pregleda oko 800 strojeva godišnje. Portugal se uključio u provedbu europske direktive (2009/128/EC i 2006/42/EC) tek 2008. godine i do sada je pregledano 799 strojeva za zaštitu bilja (Nunes, P. i sur., 2009). Opsežna dobrovoljna testiranja tehničkih sustava u Republici Hrvatskoj, prema navodima Banaja i suradnika (2000.) krenula su krajem prošlog desetljeća i već tada su uočeni nezadovoljavajući rezultati površinske raspodjele tekućine pri radu ratarskih prskalica. Ista grupa autora (2010.) navodi da je najvažniji čimbenik zadovoljavajuće kvalitete rada stroja za zaštitu bilja ispravnost mlaznica. Isto tako, prema Bugarinu i suradnicima (2000.), značajan problem stvaraju istrošene i začepljene mlaznice.

CILJ ISTRAŽIVANJA

Cilj istraživanja je doći do saznanja o ispravnosti rada strojeva za zaštitu bilja u Republici Hrvatskoj na uzorku od 500 strojeva kroz provođenje europske direktive 2009/128/EC i 2006/42/EC i Zakona o održivoj uporabi pesticida.

MATERIJAL I METODE ISTRAŽIVANJA

U Pravilniku o uspostavi akcijskog okvira za postizanje održive uporabe pesticida (NN 142/12) u članku 43. pod nazivom “**Učestalost redovitih pregleda uređaja**“ navedeno je da uređaji podliježu redovitom pregledu najmanje jednom u razdoblju od tri godine, odnosno barem jednom do 26. 11. 2016. godine. Isto tako novi uređaji koji su kupljeni nakon 1. siječnja 2013. godine ne podliježu redovitom pregledu nego nakon upisa u FIS bazu Ministarstva Poljoprivrede dobivaju znak o provedenoj kontroli za naredno razdoblje od pet godina. Međutim, uređaji koji su proizvedeni prije 1995. godine moraju biti pregledani najkasnije do 26. studenoga 2014. godine. Upravo ovaj članak navedenog pravilnika direktno je utjecao na odabir potencijalnih korisnika u ispitivanju u ovoj godini testiranja.

Testiranja su provedena prema EN 13790 (I i II) koja je glavni temelj europske direktive 2009/128/EC i 2006/42/EC. Na strojevima je obavljena kontrola:

- ispravnosti crpki

- ispravnosti mlaznica
- ispravnosti manometara
- pojave kapanja/“curenja“ tekućine na vodovima poslije i za vrijeme rada
- ispravnosti krila prskalica
- poprečne raspodjele tekućine prskalice u radu pri čemu je utvrđivan koeficijent varijacije (%) i dr.

Za provedbu testiranja korištena je oprema Ispitne stanice 001 Zavoda za mehanizaciju Poljoprivrednog fakulteta u Osijeku. Zavod posjeduje svu potrebnu opremu za provedbu testiranja tehničkih sustava u zaštiti bilja po normi EN 13790 koja je osnova za provedbu direktiva 2009/128/EC i 2006/42/EC Europske unije i za dobivanje ovlaštenja za rad svake ispitne stanice u Republici Hrvatskoj.

Kapacitet crpke

Prema normi EN 13790 odstupanje kapaciteta crpke (l/min) može iznositi najviše do 10% od njenog nazivnog kapaciteta. Mjerenje kapaciteta crpke obavljeno je elektromagnetnim mjeračem protoka tvrtke Krohne kao što je prikazano na slici 1.



Slika 1 Elektromagnetni mjerač kapaciteta crpke tvrtke *Krohne*

Tlakomjer-Manometar

Komparator tlaka Volos (slika 2.) prema standardu EN 837-1 posjeduje kontrolni uređaj promjera 160 mm za mjerenje tlaka (umjeren-certifikat) s klasom točnosti 0.6 s mjernim područjem do 25 bar. Na uređaj Volos postavlja se kontrolni uređaj koji se želi provjeriti. Uređaji za kontrolu tlaka koji se ugrađuju na tehničke sustave u zaštiti bilja trebaju imati minimalni promjer od 63 mm te točnost uređaja koji se ispituje od $\pm 0,2$ bar za ispitno područje od 0 do 2 bar. Ako se radi o većem ispitnom području dopuštena odstupanja mogu iznositi do $\pm 10\%$.



Slika 2 Komparator tlaka *Volos*

Mlaznice

Europski standard nalaže zamjenu svake mlaznice koja ima protok veći od 10% s s odstupanjem protoka $>10\%$ obzirom na deklarirani protok pri tlaku $p=3,0$ bara. Mjerenje protoka mlaznica na raspršivačima obavljeno je s menzurama volumena 2 l s podjelom od 50 ml (slika 3.). Kontrola protoka tekućine kroz mlaznice ratarskih prskalica obavljena je uporabom elektronskog mjerača protoka tvrtke AAMS.



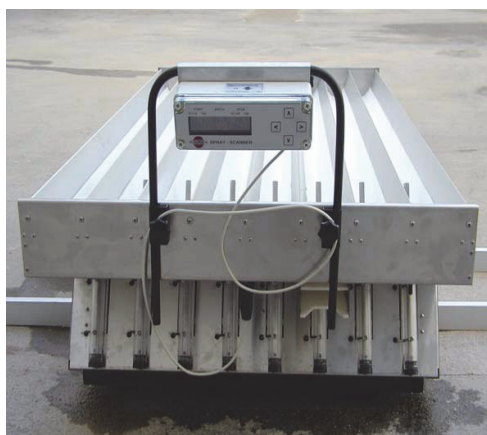
Slika 3 Menzure za mjerenje protoka mlaznica na raspršivača-orošivača



Slika 4 Elektronski mjerač protoka mlaznica belgijske tvrtke AAMS

Poprečna raspodjela tekućine ratarskih prskalica

Ispitna stanica 001 Zavoda za mehanizaciju Poljoprivrednog fakulteta u Osijeku posjeduje i uređaj spray scanner tvrtke AAMS (slika 4.) kojim se utvrđuje poprečna raspodjele tekućine ratarskih prskalica.



Slika 5 Ispitivanje površinske raspodjele tekućine kod ratarske prskalice

REZULTATI ISTRAŽIVANJA

U istraživanju su prikazani rezultati provjere 500 tehničkih sustava od čega je 115 strojeva ili 23% bilo proizvedeno u razdoblju od 1995. do 2013. godine. Ostali strojevi (385 strojeva) ili 77 % proizvedeni bili su u razdoblju do 1995. godine. Iz ovih podataka vidljivo je da su u uzorak uvršteni strojevi stariji od 18 godina.

Kapacitet ugrađenih crpki (l/min)

Da bi crpke u potpunosti mogle osigurati dovoljnu količinu tekućine za nesmetan rad mlaznica te osigurale povrat u glavni spremnik između 5 i 10 % od kapaciteta spremnika. Testiranjem je utvrđeno da 132 crpke ili njih 24,6 % ima smanjenje kapaciteta crpke > 10 %. Prema tome ostalih 75,4 % zadovoljava traženi kriterij protoke.

Tlakomjer-Manometar

Ispravnost uređaja za mjerenje tlaka direktno utječe na količinu protoke mlaznica. Dobiveni rezultati pokazuju da 234 uređaja od ukupno 500, odnosno njih 46% ne zadovoljava jedan od traženih kriterija ispravnosti. Od 234 uređaja njih 121 ili 51,7% bilo je potpuno neispravno. Na 38 (16,2%) uređaja utvrđena je neispravnost veličine mjerne skale, dok su preostali uređaji, njih 32% radili utvrđenim odstupanjem u plusu ili minusu.

Mlaznice

Provjerava protoka (l/min) pojedinačnih mlaznica, a i ukupno po stroju utvrđivanjem poprečne raspodjele uređajem spray scanner tvrtke AAMS, utvrđena su značajnija odstupanja kod ispitana 154 uređaja. Na 72 uređaja utvrđena je ugradnja mlaznica različitih protoka (l/min). Na preostala 82 uređaja utvrđena su standardna odstupanja protoka > od 10% od deklarirane vrijednosti pri tlaku $p = 3$ bara

Takav neujednačen rad mlaznica uvjetovao je i lošu poprečnu raspodjelu-distribuciju tekućine. Kod 346 prskalica poprečna raspodjela bila je unutar dozvoljenih granica od 20%, a kod 156 uređaja utvrđena je poprečna distribucija tekućine s odstupanjem < 10%

Brtvljenje toka tekućine

Brtvljenje na spojevima fleksibilnih/elastičnih vodova, nosača mlaznica, regulatora i drugih mjesta toka tekućine, izuzetno je važno kao s razloga gubitaka škropiva, tako i posebno zbog prevencije onečišćenje (kontaminacije) okoliša. Veliki broj tehničkih sustava nije tijekom ispitivanja zadovoljio ovaj kriterij. Uz podršku servisne službe sva mjesta na kojima su uočeni neki od oblika istjecanja tekućine bili su odmah otklonjeni (promjenom brtvi ili dotezanjem obujmica ili izmjenom protukapajućih ventila).

ZAKLJUČAK

Prvim službenim testiranjem strojeva za zaštitu bilja u Republici Hrvatskoj propisanim normom *EN 13790*, evidentirano je prilično loše stanje koje je posljedica prisutnosti tehnološki i eksploatacijski zastarjelih strojeva, te strojeva u zatečenom stanju, koji de facto ne mogu zadovoljavajuće obavljati zaštitu bilja. Od ukupno testiranih strojeva njih 75,40%

zadovoljava standarde s obzirom na kapacitet crpke; 54,00% s obzirom na ispravnost manometra i 69,20% s obzirom na površinsku raspodjelu tekućine. Tek nakon zamjene neispravnih dijelova, ispitivani strojevi zadovoljavaju kriterije ispravnosti tehničkih sustava u zaštiti bilja te mogu dobiti znak o obavljenom tehničkom pregledu. Sve navedeno je vrlo bitan posao koji osigurava zdravu hranu i okoliš u Republici Hrvatskoj.

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TESTING TECHNICAL SYSTEMS IN PLANT PROTECTION IN REPUBLIC OF CROATIA

SUMMARY

With Croatian entry in EU the directives 2009/128/EC i 2006/42/EC were inherited. This directive provides for mandatory review of technical systems in plant protection (mistblowers and boom sprayeres). The directive was introduced in Regulation on sustainable use of pesticides (NN 142/12), according to which all devices in crop protection until the November, 2016 must have a label on the regular technical overview. Devices manufactured before 1995, must have a label until November, 2014. Due to the aforementioned problems and approaching deadlines, directive becomes current and they should be given additional significance. In this paper, the methodology of performing with used equipment is showed at section of examined machines (approx. 500) in Republic of Croatia (test station 001 and 004). Of the total tested machines, 75.40% of them are in standards within the pump capacity, 54.00% of tested machines are with correct pressure gauge and 69.20% of tested machines have proper surface distribution of liquid

Key words: mistblower, sprayer, nozzle, EN 13790 standard, testing



MECHANICAL AND THERMAL WEED CONTROL AND USE OF BIO-PREPARATIONS IN WINTER OILSEED RAPE

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SUMMARY

Researches were conducted at the Experimental Station of Aleksandras Stulginskis University. This study aims to identify and assess the impact of thermal and mechanical weed control methods on winter oilseed rape (WOR) crops and weed competitiveness during the autumn vegetation period in an organic farming system, with and without the use of bio-preparations. Experimental treatments were: non-chemical weed control methods (Factor A): 1 – thermal (water steam), 2 –mechanical (inter-row loosening); and bio-preparations (Factor B): 1 – no application and 2 – with application. During experiment in the autumnal vegetation period before the use of weed control methods in the organic WOR crop, up to 21 weed species were found in 14 families, including up to 19 annuals and only up to three perennials. In 2013, meteorological conditions were more favourable for the growth and development of WOR than in 2012, therefore in 2013, the density of the WOR crop was on average 38.8% higher. Prior to the weed control application in 2013, the number of weed seedlings was, on average, 1.9 times higher than in 2012, but the dense oilseed rape crop had higher smothering capacity. In 2013, in WOR crop without the use of bio-preparations, the number of germinated weed seedlings was higher (1.2–1.3 times) compared to the crop where bio-preparations were used. The use of bio-preparations in the thermal weed control plots significantly ($P \leq 0.05$) reduced the number of weed seedlings (20.4%). The assessment of the efficiency of weed control methods revealed, that without the use of bio-preparations, mechanical

weed control efficiency was 3.6 to 4.5 times higher than the thermal weed control efficiency. Bio-preparations enhanced thermal weed control efficiency (from 4.5 to 21.8%), but mechanical weed control efficiency was reduced from 6.8 to 23.1%.

Key words: *winter oilseed rape, weeds, weed control methods, bio-preparations, organic farming system*

INTRODUCTION

Organic (non-chemical) farms of oilseed rape are not expanding due to problems with weeds, diseases, inadequate pest control, and low seed yield (Valantin-Morison et al., 2008). Weeds species composition and abundance in crops is due to many factors, including the characteristics of the soil, crop rotation, competitiveness of agricultural plants, crop density, soil cultivation level and fertilisation (Hanzlik et al., 2011; Čiuberkis and Vilkonis, 2013). Weed control in crop rotations can be successful with the proper choice of crops with an optimal vegetation period and competitive characteristics (Kocjan Ačko and Šantavec, 2010). Catch crops and their mixtures included in crop rotation is one of the measures to lower crop weediness, supply biogenic elements (Masilionytė and Maikštėnienė, 2010), and maintain soil productivity. Rotation of winter and spring crops maintains the biodiversity of crops and, at the same time limits the propagation and spread of weeds of different biological groups (Arlauskienė and Maikštėnienė, 2004; Brainard et al., 2008). The smothering capacities of different agricultural crops depend on the biological properties of the plants, tillage, fertilisation, seed rate and sowing time (Bullied et al., 2006). Rape has a lower weed smothering capacity than barley and winter wheat due to the long period of their rosette development (Velička et al., 2002). Marcinkeviciene et al. (2006) found that the weed smothering capacity of oilseed rape crops of different densities are dependent on the plant leaf area index, oilseed rape aboveground biomass and solar energy flow to the surface of the soil in the blooming stage.

The most efficient method of crop protection is integrated weed management, which combines a variety of weed control methods (Barberi et al., 2009; Young, 2012). Inter-row mechanical weed control is practiced in organic farms and can significantly reduce crop weediness, but mechanical weed control in oilseed rape cultivation is of limited use. Thermal weed control is a newly developed method for controlling weeds. This method is based on heat spread regularities, using thermo-engineering techniques and equipment. A heat source, which creates a high temperature environment around the plant, is used for thermal weed control (Sirvydas and Kerpauskas, 2012). Several methods, such as flame (Ulloa et al., 2012, Datta and Knezevic, 2013), hot water (Hansson and Ascard, 2002), hot foam (Kempenaar and Spijker, 2004), and water steam, have been used in thermal weed control (Kerpauskas et al., 2006; Virbickaitė et al., 2006; Barberi et al., 2009; Staniulienė, 2010; Sirvydas and Kerpauskas, 2012). Virbickaitė et al. (2006) found that the efficiency of thermal weed control using steam for annual weeds was 22.5% higher than mechanical weed control; however, the effectiveness of mechanical weed control on perennial weeds was 32.0% higher than using the thermal method. Kerpauskas et al. (2006) reported that thermal weed control using steam lowered weed dry matter mass by 44.0% and the yield of the barley grains increased by 22.0%. Thermal weed control using steam is most effective

in the weed germination stage when the soil is undisturbed and weed seed germination is not activated (Sirvydas et al., 2008).

As the use of organic fertilisers and bio-preparations increases, it is critical to investigate their effectiveness on organic crops. Research conducted in Lithuania showed the use of liquid organic fertilisers and growth promoters have a significant influence on grain yield and plant biometrical indices (Jablonskytė-Raščė et al., 2012, Pekarskas, 2012). There have been multiple investigations on oilseed rape cultivated in an organic system in many countries (Dejoux et al., 2003; Holzapfel et al., 2009; Engström et al., 2014), but there is lack of such studies for Lithuanian climatic conditions, especially with current and innovative pest and weed control methods.

This study aims to identify and assess the impact of thermal and mechanical weed control methods and the use of bio-preparations on winter oilseed rape and weed competitiveness in organic farming during an autumnal vegetation period.

METHODS

Field experiments

Field experiments were performed in 2012 and 2013 at the Experimental Station of Aleksandras Stulginskis University (54°53' N, 23°50' E). This study investigated the influence of different weed control methods on winter oilseed rape (*Brassica napus* L. ssp. *oleifera biennis* Metzg.) and weed competitiveness in organic farming with and without the use of bio-preparations. WOR was cultivated in a soil with a regular humus layer (23–25 cm). The soil was (IDg4-k) *Calc(ar)i-Endohypogleyic Luvisol (LVg-n-w-cc)*. The soil agrochemical properties (mean data for 2012 and 2013) were as follows: pH 7.10, humus 1.85%, and mobile nutrients P_2O_5 234 mg kg⁻¹ and K_2O 106 mg kg⁻¹.

There were two main factors in the experiment. Factor A was non-chemical weed control methods, including the following treatments: 1 – thermal (water steam), 2 – mechanical (inter-row loosening). Factor B involved bio-preparations and included the following treatments: 1 – no application and 2 – with application.

The WOR variety ‘Sunday’ (3 kg ha⁻¹) was cultivated in a certified organic (non-chemical) field. Before crop were perennial grasses: red clover (*Trifolium pratense* L.) and timothy grass (*Phleum pratense* L.) for three successive years and the last year bare fallow was kept, which was fertilised with manure.

Thermal and mechanical weed controls were applied in oilseed rape crops cultivated at a wide row spacing of 48 cm. For thermal weed control, a mobile thermal water steam device was used (thermal capacity 90 kW, performance 120 kg h⁻¹, with steam-fired liquefied gas) (Fig. 1). The steam temperature was 99 °C, and the heat exposure duration was 2 s.

For mechanical weed control, inter-rows were loosened twice with a soil loosener (KOR-4.2-01, Ukraine) at the 3–4 leaf stage of rape. In the treatment where bio-preparations were used, rape seed was processed before sowing with the bioorganic fertiliser (fulvic and humic acids 9.09 g l⁻¹, N 0.35 g l⁻¹, P 0.73 g l⁻¹, K 2.49 g l⁻¹, Mg 283.8 mg l⁻¹, B 0.36 mg l⁻¹, Cu 0.90 mg l⁻¹, Fe 110.5 mg l⁻¹, Mn 435.7 mg l⁻¹, Mo 713.1 mg l⁻¹, Zn 345.5 mg l⁻¹, Co 51.95 mg l⁻¹, Se 0.138 mg l⁻¹, Cd 0.231 mg l⁻¹, Cr 0.02 mg l⁻¹, Ni 1.30

mg l⁻¹, organic material 9.09 g l⁻¹, C_{org} 4.60 g l⁻¹ (0.5 l bioorganic fertiliser + 10 l of water per ton of seed), and during vegetative growth, the crop was sprayed with bio-preparations of 0.3% (40% *Azadirachta indicaseed* oil soap and 40% organic material) (only in 2012) and 0.3% (50% *Quassia amara* extract, 50% natural origin oleic acid potassium soap and 85% organic material). Four replications were performed in this experiment. The size of the plot was 60.0 m², and the observation plot was 20.0 m². Prior to the crop was black fallow.

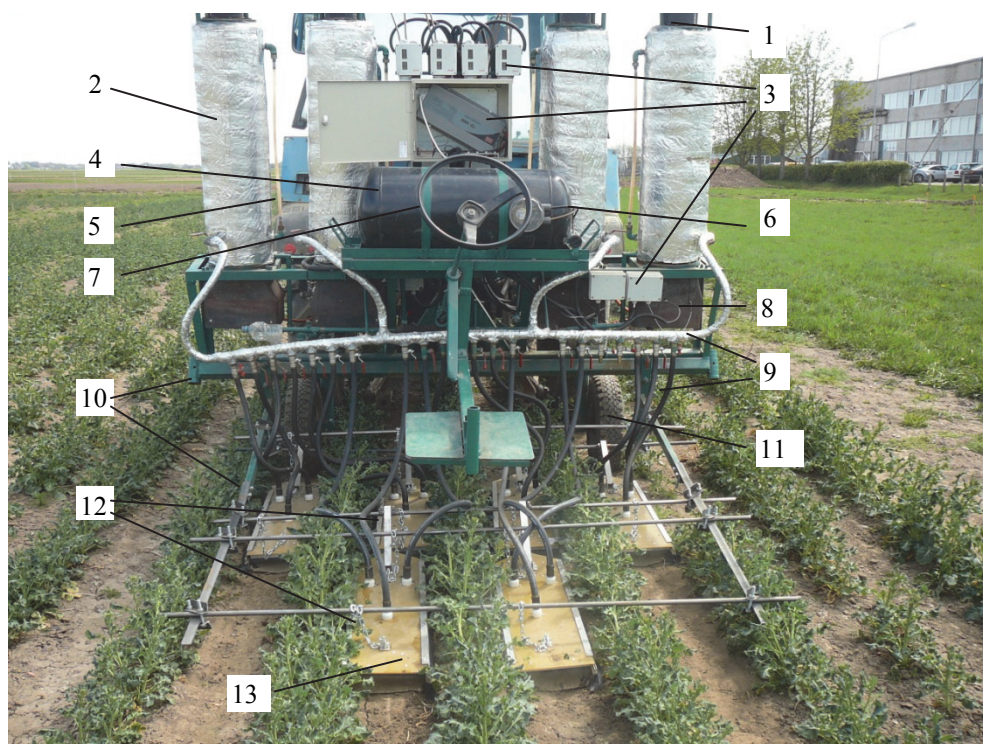


Fig. 1 Mobile thermal water steam device used for thermal weed control: 1 – the chimney; 2 – steam boiler; 3 – steam boiler protection and control equipment; 4 – liquefied gas cylinder; 5 – the meter of water level in the steam boiler; 6 – the pipe for liquefied gas supply; 7 – the driving mechanism of the device; 8 – the combustion chamber; 9 – steam delivery hose; 10 – frame, on which all equipment mounted; 11 – support wheels; 12 – the equipment for mounting of the protectors; 13 – protectors of crops from the steam.

Agrochemical characteristics of soil were measured prior to the experiments and in all replications. Combined soil samples were taken with a Nekrasov auger from the 0–25 cm soil layer. Soil pH was determined potentiometrically in 1 n KCl extract, mobile phosphorus (P₂O₅) and mobile potassium (K₂O) (mg kg⁻¹ soil) were determined using the Egner-Riehm-Domingo (A–L) method, and the humus content (%) was determined using the Tiurin method.

The density of the WOR crop (plants m^{-2}) was estimated in each replication in four 0.25 m^2 size plots. The first analysis of weed seedlings abundance was conducted prior to the application of thermal and mechanical weed control methods in three to four leaf stage of the rape. The number of weed seedlings was estimated in each replication in four randomly selected 0.10 m^2 sized plots. The second analysis was performed in marked weed accounting plots seven days after the application of weed control methods. The efficiency of different weed control methods (E) on the change in weed seedling number was calculated according to the formula: $E = \left(\frac{S_1 - S_2}{S_1} \times 100 \right) \%$, where S_1 was the weed seedling number in 1 m^2 before the weed control method was applied, and S_2 was the weed seedling number in 1 m^2 after the weed control method application.

Aboveground plant dry matter yield of oilseed rape (SM g m^{-2}) was estimated by taking samples of 10 plants from each plot and drying them at 105 °C. Examinations were performed at the Soil and Crop Ecology Laboratory of the Experimental Station of Aleksandras Stulginskis University.

Statistical analyses. Data from these experiments were statistically evaluated for quantitative characteristics using a two-way ANOVA. Statistical analysis of the data was performed using the computer program SPLIT PLOT from software package 'Selekcija' (Tarakanovas et al., 2003). If not they distributed normally, the weediness test data were transformed using the function $y = \ln x$ prior to statistical evaluation.

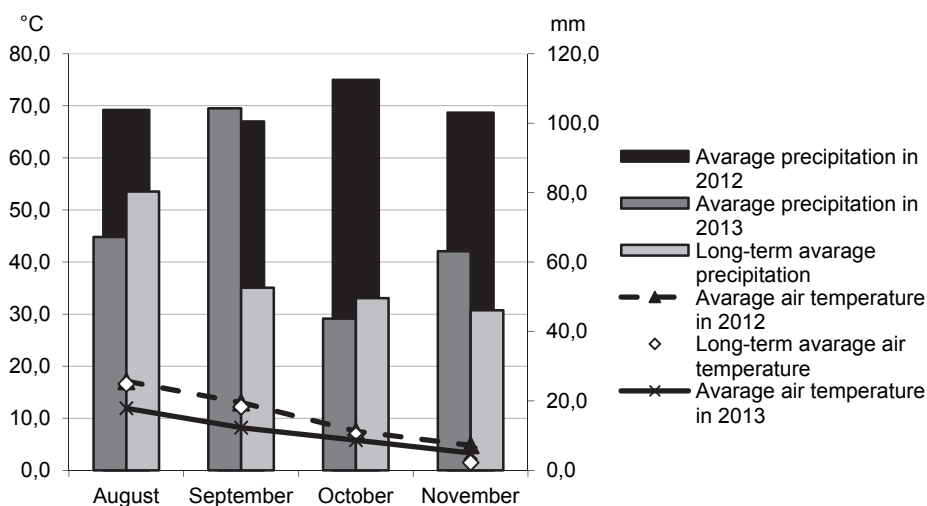


Fig. 2 Meteorological conditions

Meteorological conditions. In 2012, the WOR was sown on the 20th of August. This month was not favourable for WOR germination due to the lack of the rainfall (Fig. 2). There was sparse rain (18.9 mm) during the last ten days of this month, and the monthly hydrothermal coefficient (HTC) was 1.3 (optimal irrigation). September was favourable not only for oilseed rape but also for weed growth. The monthly mean temperature was 1.1 °C

above average and precipitation was 14.6 mm higher, compared with the long-term mean precipitation. September's HTC was 1.7 (excess irrigation). October was warm (especially the first ten days) and humid. Rainfall exceeded the long-term mean rainfall by 25.4 mm. The average temperature in November was 3.3 °C and rainfall was 22.6 mm above the long-term mean indices.

In 2013, the WOR was sown on the 17th of August. The monthly average temperature for August was 1.2 °C above the long-term mean and amount of precipitation was regular. The HTC of August was 1.2 (optimal irrigation). The average temperature of September was close to the long-term mean, though precipitation was 5.5 times higher. The HTC for September was 2.8 (excess irrigation). The amount of rainfall in October was close to the long-term mean, but the average temperature was 1.9 °C higher. The HTC for October was 1.1 (the optimum irrigation). The average temperature of November exceeded the long-term mean by 3.4 °C, and rainfall was 17 mm higher.

RESULTS AND DISCUSSION

In 2012, during the vegetation period in the autumn and before the use of any weed control methods in the WOR crop, 20 weed species were found, including 19 annuals and one perennial (*Elytrigia repens* (L.) Nevski). Weeds found belonged to 12 families (Boraginaceae, Asteraceae, Chenopodiaceae, Brassicaceae, Scrophulariaceae, Caryophyllaceae, Euphorbiaceae, Poaceae, Violaceae, Lamiaceae, Polygonaceae, and Fumariaceae). The most abundant of annual weed was *Stellaria media* (L.) Vill. (11.3–17.5 seedlings m⁻²). More favourable conditions for the growth of these weed seedlings were in the oilseed rape cultivated at a wide row spacing (48 cm) and without the application of bio-preparations. According to Arlauskienė and Maikštėnienė (2004), in thinner crops, annual weeds, especially *T. perforatum* and *Galium aparine* L. are more abundant than perennial weeds.

In the 2013 autumn vegetation period of WOR crop, 21 weed species were found including 18 annuals and 3 perennials. Weeds found belonged to 14 families (the same as in 2012 with the addition of *Equisetaceae* and *Rubiaceae*). The most abundant were *V. arvensis* (28.8–58.1 seedlings m⁻²) and *C. bursa-pastoris* (7.5–17.5 seedlings m⁻²), especially in oilseed rape crop cultivated at a wide row spacing.

Crop density is particularly important for weed control in the early stages of rape growth (Morrison et al., 1990). The rape rosette stage, in Lithuanian climatic conditions, lasts up to 30–40 days, and the smothering capacity of the crop during this period is very low (Velička, 2002). In our experiment, unfavourable meteorological conditions for rape growth and development occurred at the end of the summer and the beginning of autumn in 2012. For this reason, the rape crop was smothered by the weeds. In 2012 WOR crop density was lower in both thermal and mechanical weed control treatments with the use of bio-preparations (Table 1). During the end of the summer and autumn in 2013, meteorological conditions were more favourable for the growth and development of WOR than in 2012. For this reason, in 2013, the density of the rape crop was higher. In 2013 WOR crop density was significantly ($P \leq 0.05$) lower in plots where thermal weed control was applied with no use of bio-preparations compared with mechanical weed control. When bio-preparations were used in combination with weed control no significant ($P \leq 0.05$) differences estimated comparing thermal and mechanical weed control methods.

Table 1 The influence of different weed control methods and bio-preparations on the competitiveness of winter oilseed rape and weeds, 2012–2013.

Weed control method (Factor A)	Bio-preparations (Factor B)					
	no application			with application		
	Oilseed rape crop density, plants m ⁻²	Weed seedlings ¹ m ⁻² (S ₁)	Weed seedlings ² m ⁻² (S ₂)	Oilseed rape crop density, plants m ⁻²	Weed seedlings ¹ m ⁻² (S ₁)	Weed seedlings ² m ⁻² (S ₂)
2012						
Thermal	57,3a*	30,6b	28,1a	30,5a*	25,0b	17,5b
Mechanical	48,5a	51,3a	32,5a*	32,8a	69,4a	60,0a*
2013						
Thermal	79,9b	113,8a*	96,2a	87,1a	90,6a*	72,5a
Mechanical	97,0a	76,9b	34,4b	85,8a	60,6b	31,2b

Note: means not sharing a common letter (a, b, c) (Factor A) and with asterisks (Factor B) are significantly different ($P \leq 0.05$). S₁ – the weed seedling number in 1 m² before the weed control method was applied, S₂ – the weed seedling number in 1 m² after the weed control method application.

Prior to the weed control application in 2012, the number of weed seedlings in plots of thermal weed control was significantly ($P \leq 0.05$) lower (1.7–2.8) both with and without application of bio-preparations compared with mechanical weed control plots. In plots without use of bio-preparations it was influenced by crop density. The influence of bio-preparations on weed seedling number was not significant ($P \leq 0.05$).

In 2013, the number of weed seedlings was, on average, 1.9 times higher than in 2012, but the dense oilseed rape crop had higher smothering capacity. In the rape crop with wide 48 cm inter-rows under sufficient humidity and more favourable light conditions the spread of the weeds was high. The number of weed seedlings in this crop was 60.6–113.8 m⁻². In WOR crop without the use of bio-preparations, the number of germinated weed seedlings was higher (1.2–1.3 times) compared to the crop where bio-preparations were used. The use of bio-preparations in the thermal weed control plots with wide inter-rows significantly ($P \leq 0.05$) reduced the number of weed seedlings (20.4%).

In 2012, after thermal and mechanical weed controls were applied, the lowest number (17.5 m⁻²) of weed seedlings was in thermal weed control plots with application bio-preparations. It was significantly ($P \leq 0.05$) lower than in mechanical weed control plot with the use of bio-preparations. The thermal weed control method was the most efficient for annual dicotyledonous weeds. The number of the most abundant weed, *S. media*, in rape decreased by 26.5%. Virbickaitė et al. (2006) suggested that by using water steam for weed control, the spread of *S. media* in crop can be reduced up to 100%. The number of weed seedlings did not significantly ($P \leq 0.05$) differed using thermal and mechanical weed control methods without the application of bio-preparations.

After thermal and mechanical weed control application in 2013, the number of weeds was significantly ($P \leq 0.05$) lower (2.3–2.8) in mechanical weed control plots with and without use of bio-preparations. Mechanical weed control in the WOR crop decreased the number of the most abundant *V. arvensis* by 85.3% without use of bio-preparations and by 75.4% using them. The number of weed seedlings in the plots after application thermal and mechanical weed control in combination with bio-preparations was not significantly ($P \leq 0.05$) different compared to plots where bio-preparations were not used.

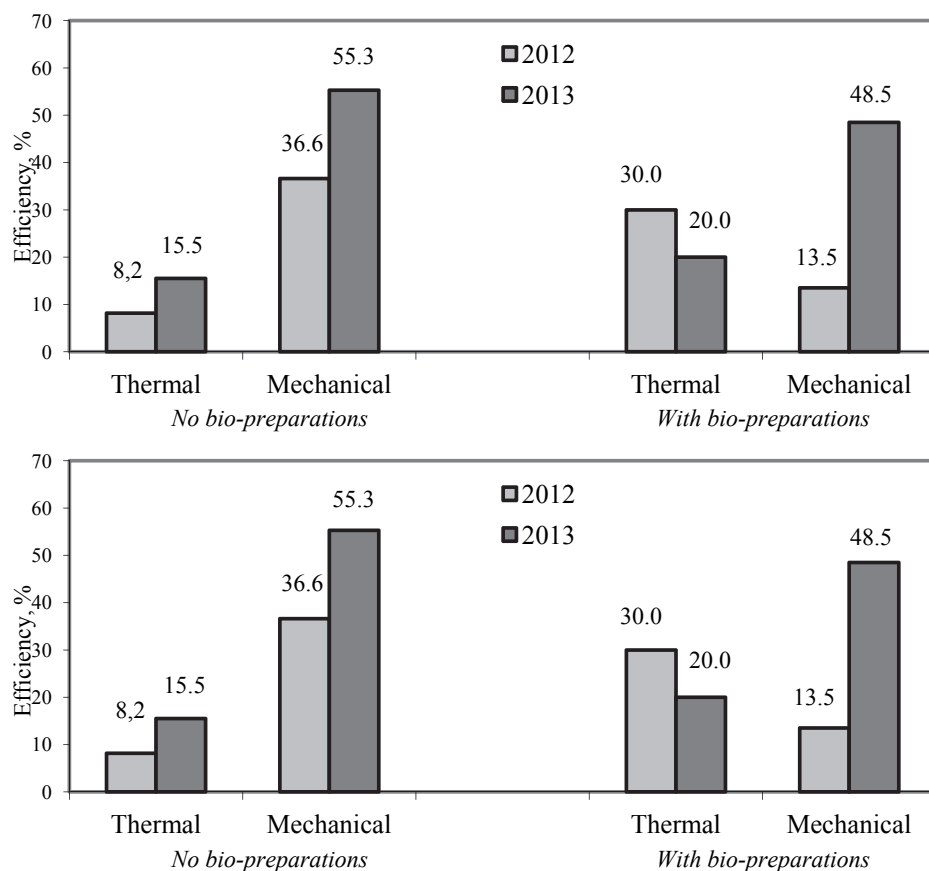


Fig. 3 The efficiency of different weed control methods and bio-preparations on weed seedlings in the autumn vegetation period, 2012–2013.

The assessment of the efficiency of different weed control methods on weed seedlings revealed, that without the use of bio-preparations, mechanical weed control efficiency was 3.6 to 4.5 times higher than the thermal weed control efficiency in 2012 and 2013 (Fig. 3).

Using bio-preparations (only in 2013), the efficiency of the mechanical weed control was 2.4 times higher than using thermal weed control. In 2012, the thermal weed control

efficiency was 2.2 times higher than the mechanical weed control efficiency. Bio-preparations enhanced thermal weed control efficiency (from 4.5 to 21.8%) in both experimental years. Mechanical weed control efficiency was reduced from 6.8 to 23.1% by application of bio-preparations.

CONCLUSIONS

During experiment in the autumnal vegetation period before the use of thermal and mechanical weed control methods in the organic winter oilseed rape crop, up to 21 weed species were found, including up to 19 annuals and up to three perennials. Weeds found belonged to 14 families. The most abundant of annual weeds were *Viola arvensis* (28.8–58.1 seedlings m⁻²), *Stellaria media* (L.) Vill. (11.3–17.5 seedlings m⁻²), and *Capsela bursa-pastoris* (7.5–17.5 seedlings m⁻²). More favourable conditions for the growth of these weed seedlings were in the oilseed rape cultivated without the application of bio-preparations.

In 2013, meteorological conditions were more favourable for the growth and development of winter oilseed rape than in 2012. For this reason, in 2013, the density of the winter oilseed rape crop was higher. In 2013, winter oilseed rape crop density was significantly ($P \leq 0.05$) lower in plots where thermal weed control was applied with no use of bio-preparations compared with mechanical weed control. When bio-preparations were used in combination with weed control no significant ($P \leq 0.05$) differences estimated comparing thermal and mechanical weed control methods.

Prior to the weed control application in 2013, the number of weed seedlings was, on average, 1.9 times higher than in 2012, but the dense oilseed rape crop had higher smothering capacity. In 2012, the number of weed seedlings in plots of thermal weed control was significantly ($P \leq 0.05$) lower (1.7–2.8) both with and without application of bio-preparations compared with mechanical weed control plots. The influence of bio-preparations on weed seedling number was not significant ($P \leq 0.05$). In 2013, in winter oilseed rape crop without the use of bio-preparations, the number of germinated weed seedlings was higher (1.2–1.3 times) compared to the crop where bio-preparations were used. The use of bio-preparations in the thermal weed control plots significantly ($P \leq 0.05$) reduced the number of weed seedlings (20.4%).

The assessment of the efficiency of different weed control methods on weed seedlings revealed, that without the use of bio-preparations, mechanical weed control efficiency was 3.6 to 4.5 times higher than the thermal weed control efficiency in 2012 and 2013. Using bio-preparations (only in 2013), the efficiency of the mechanical weed control was 2.4 times higher than using thermal weed control. In 2012, the thermal weed control efficiency was 2.2 times higher than the mechanical weed control efficiency. Bio-preparations enhanced thermal weed control efficiency (from 4.5 to 21.8%) in both experimental years. Mechanical weed control efficiency was reduced from 6.8 to 23.1% by application of bio-preparations.

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COMPARATIVE STUDY REGARDING PRECISION OF SOWING DEVICES DISTRIBUTION

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ABSTRACT

Precision for sowing is essential in order to achieve sowing quality works for hoeing plants, ultimately influencing the high productions obtaining. This paper presents a comparative study regarding the sowing accuracy obtained in laboratory conditions on a special stand, using 3 different row units: one individual transmission and two centralized transmissions for the seed distribution devices. The researches were developed for three working speeds, three different plant densities per hectare using corn as seed material.

Key words: precision seeder, seed-metering device, transducer, control system,

INTRODUCTION

Promoting the research in the sowing precision domain aims to applying of optimum solutions in designing precision seeders for hoeing plants in order to obtain the qualitative working indexes according to modern agro-technical requirements related to sowing.

Improving, modernizing, simplifying the construction and adjusting the seeds distributing operations are necessary because of disturbing factors which can affect the sowing precision, factors determined by seeds quality, small volume, reduced weight and irregular shape, as well as the precision seeder wear state: clogged section, blocked distribution, broken transmission chain, seeds scraper out of order, insufficient pressurisation, lack of seeds in supplying hopper. [1]

In order to evaluate the performances of pneumatic precision seeders used in corn crops, Li used an equipment comprising a microcontroller and a wireless chip, which will alert the operator in case of double seeds or lack of seeds. The equipment can monitor the sowing

process, the error rate being able to be controlled instantaneously in a percentage of 97,2 % [2].

Experimental researches have been performed with a row unit of precision seeder for hoeing plants with fertilizer SPF8M, a synthesis of qualitative working indexes being drawn up, which represents the deviation from quantity of seeds distributed (sowing rates), for usual norms of 50000...70000 plants/hectare for corn and sunflower. The researches were performed in laboratory on a stand with fixed row unit, and the disc of seeds distribution was driven by rotational speed appropriate to displacement conditions of precision seeder without skidding. For obtaining the sowing machine movement comparing to soil, under the sowing section a band which displaced with theoretical forward speed, without skidding, was placed [3], [7].

By using adequate software data regarding worked surface, quota per hectare, moving speed and the operation quality of each row unit. Precision seeders equipped with this kind of automated supervising systems keeping optimal density of plants is assured, and thus superior crops are produced.[4], [5]. Were designed software in which the only input data is the working width of the precision seeder and functional parameters are monitored in real time: the speed of the agricultural equipment, the area sown in a period of time, productivity achieved etc. [6]

MATERIAL AND METHODS

Experimental researches aiming to emphasize the differences regarding the sowing precision of three row units were performed on a specialized stand SPS-3 (fig. 1) within INMA București, on the stand being mounted 3 different row units of precision seeders: SPC 6 (S_1) produced by Mecanica Ceahlau – row unit with individual transmission of distribution device, respectively: SPF 6 (S_2) and SEMA 6 (S_3), produced by INMA Bucharest – row units endowed with centralized transmission of distribution devices.

Active elements of seeds distribution devices are represented by discs with holes, (dimensions, disc diameter, holes diameter), the seeds driving being achieved by creating a pressure difference in face of holes (assured by vacuum generator), and evacuation under the action of own weight, determined by depressure interruption just in face of holes where seeds are retained in the ditch open by the share.

Stand is endowed with three transducers with laser SICK (for measuring and transform with high precision the time interval between two seeds), mounted on each row unit, a PLC Mitsubitshi, operating terminal with touchscreen, vacuum generator, invertor, and 2 motors for driving the 3 sections. The block operating scheme of stand SPS 3 is shown in fig. 2.



Fig. 1 Stand SPS 3; 1 – section SPC 6; 2 – section SPF 6; 3 – section SEMA 6; 4 – frame; 5 – electric motor for simulating the working speed (0-12km/h); 6 – laser transducers SICK; 7 – frame; 8 – operating terminal

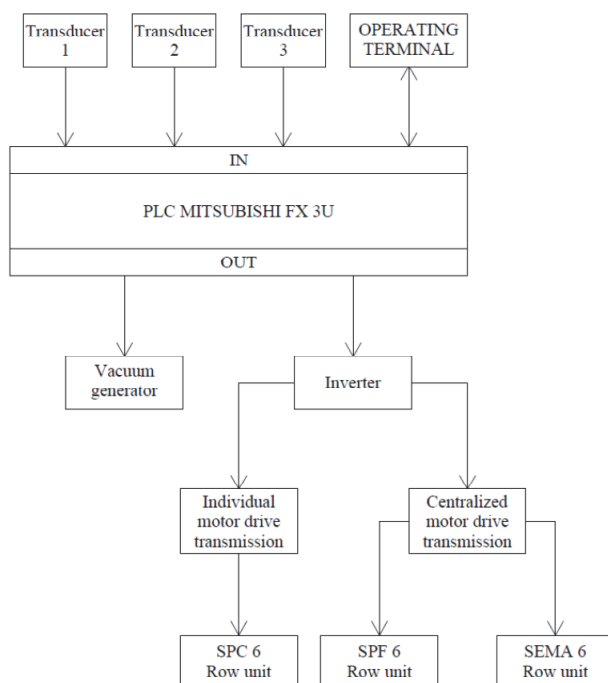


Fig. 2 The block operating scheme of stand SPS 3

Transducers with laser SICK, FLG2-20025011 model have a response time $<0,1$ ms and a detection surface of 250 mm x 200 mm, their role being of measuring and transform into space the time falling period between two seeds, which they compare afterwards to reference space (x_{ref}) [9].



Fig. 3 Laser transducers FLG2-20025011 mounted on the 3 sections of SPS 3 stand; 1 – row unit SPC 6 and laser transducer FLG2-20025011; 2 – row unit SPF 6 and laser transducer FLG2-20025011; 3 – row unit SEMA 6 and laser transducer FLG2-20025011

Experimenting method:

- Volumetric mass and 1000 seeds mass were determined ;
- Hoppers were supplied with corn seeds;
- Input data: density of plants per hectare, distance between rows, number of tested seeds, working speed, number of holes per distributing disc, were introduced;
- Specialized software calculated (based on input data) the theoretical interval between seeds in row;
- Electric motor driving the tested row unit was started using an inverter for correlation between the belt's working speed and the rotational speed of the electric motor;
- It was waited till transducers passed the number of seeds tested;
- Results were graphically displayed (fig. 4).

Specialized software of processing the experimental data is based on a system of statistically processing the experimental data [8], the reference element being the theoretical interval (adjusted) between seeds in row x_{ref} , real interval between two successive seeds x_j being determined on stand by means of laser transducers SICK (by transforming the falling time in space), considering:

- Double any real interval $x_j < 0,5 \cdot x_{ref}$;
- Normal interval any interval: $0,5 \cdot x_{ref} < x_j < 1,5 \cdot x_{ref}$;
- Lack any real interval $x_j > 1,5 \cdot x_{ref}$.

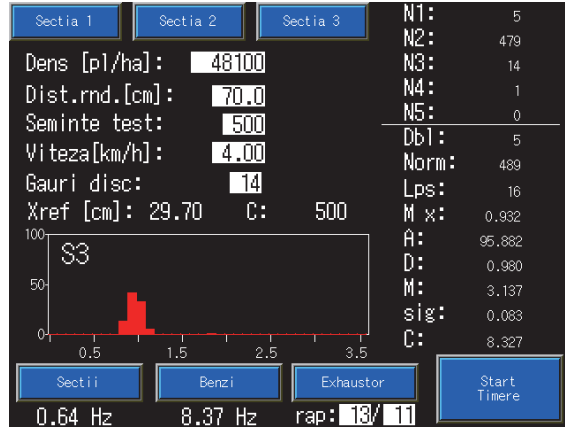


Fig. 4 Window graphically presenting the results

Values determined x_j were grouped in spanning intervals $0,1 \cdot x_{ref}$ on one side and the other of value x_{ref} thus:

$$\begin{aligned} & (0,0 \cdot x_{ref}, 0,1 \cdot x_{ref}] \\ & (0,1 \cdot x_{ref}, 0,2 \cdot x_{ref}] \\ & (0,2 \cdot x_{ref}, 0,3 \cdot x_{ref}] \\ & \dots \\ & (3,3 \cdot x_{ref}, 3,4 \cdot x_{ref}] \\ & (3,4 \cdot x_{ref}, 3,5 \cdot x_{ref}] \\ & (3,5 \cdot x_{ref}, +\infty] \end{aligned}$$

For each interval defined, the adimensional variable X_i , was associated to the following expression:

$$X_i = \frac{x_i}{x_{ref}} \quad (1)$$

where x_i represents the average value of interval considered.

There were calculated:

$$N_1 = \sum n_i \text{ for } 0,0 < X_i \leq 0,5 \quad (2)$$

$$N_2 = \sum n_i \text{ for } 0,5 < X_i \leq 1,5 \quad (3)$$

$$N_3 = \sum n_i \text{ for } 1,5 < X_i \leq 2,5 \quad (4)$$

$$N_4 = \sum n_i \text{ for } 2,5 < X_i \leq 3,5 \quad (5)$$

$$N_5 = \sum n_i \text{ for } 3,5 < X_i \quad (6)$$

where n_i represents the number of apparitions of X_i value

There were calculated:

N – total number of intervals:

$$N = N_1 + N_2 + N_3 + N_4 + N_5 \quad (7)$$

n_2 – number of doubles:

$$n_2 = N_1 \quad (8)$$

n_l – number of seeds suitably sown:

$$n_l = N - 2 \cdot n_2 \quad (9)$$

n_0 – number of pockets missing:

$$n_0 = N_3 + 2 \cdot N_4 + 3 \cdot N_5 \quad (10)$$

N' – number of theoretical intervals:

$$N' = N_2 + 2 \cdot N_3 + 3 \cdot N_4 + 4 \cdot N_5 \quad (11)$$

M_X – average of dimensional variable X for seeds appropriately sown:

$$M_X = \frac{\sum n_i \cdot X_i}{N_2} \quad (12)$$

where $0,5 < X_i \leq 1,5$

Calculation of qualitative indexes

A – quality index of supplying

$$A = \frac{n_l}{N'} \times 100 [\%] \quad (13)$$

D – index of doubles:

$$D = \frac{n_2}{N'} \times 100 [\%] \quad (14)$$

M – index of missing seeds:

$$M = \frac{n_0}{N} \times 100 [\%] \quad (15)$$

σ – theoretical deviation (placing precision):

$$\sigma = \sqrt{\left[\frac{\sum (n_i \cdot X_i^2)}{N_2} - M_X^2 \right]} \quad (16)$$

C – variation coefficient.

$$C = \sigma \times 100 [\%] \quad (17)$$

RESULTS AND DISCUSSION

There were performed determinations of interval between seeds sown at the three row units, with six repetitions, at three planting densities (48100; 49950; 51948 pl/ha) on a length appropriate to 500 seeds sown.

In fig. 5 is shown the variation of sowing precision for the 3 row units tested at a plants density of 48100 pl/ha.

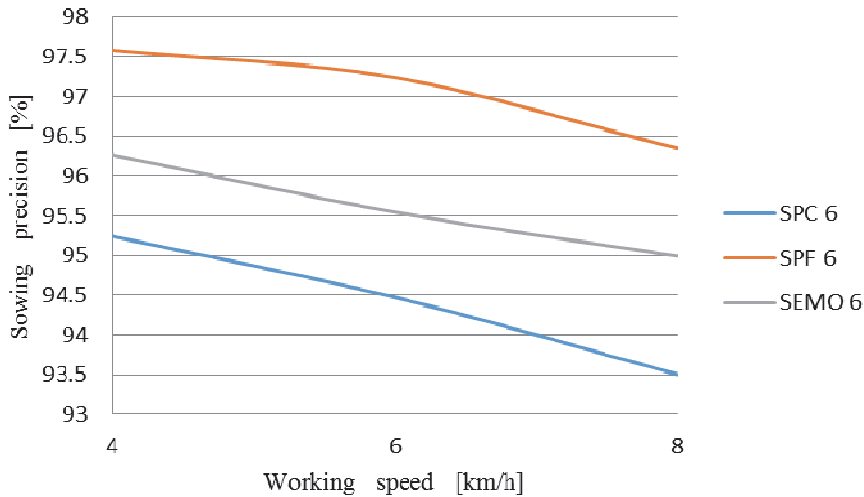


Fig. 5 Graphic of sowing precision of 3 row units tested at a plant density of 48100 pl/ha

In fig. 6 is shown the sowing precision related to working speed for SPF 6 row unit.

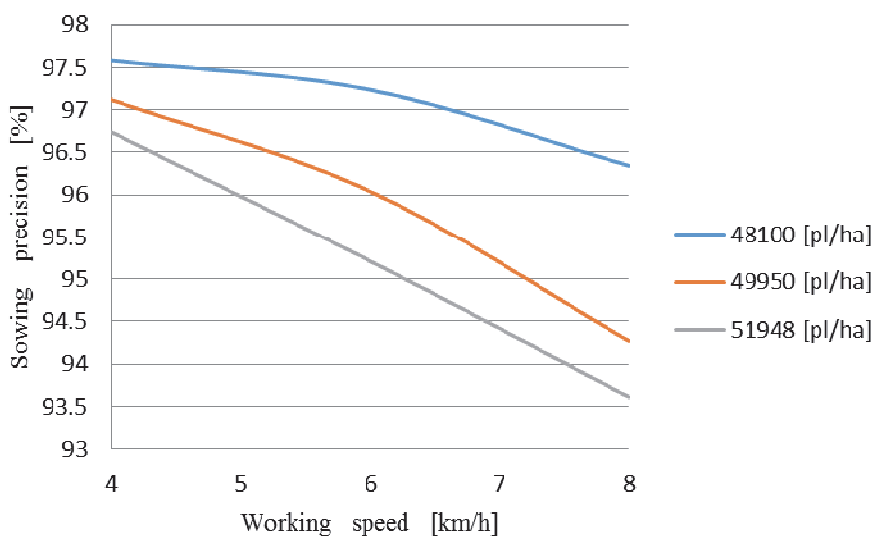


Fig. 6 Graphic of sowing precision related to working speed for SPF 6 row unit.

In table 1 are shown the qualitative indexes for precision seeder row unit SPC 6

Table 1 Qualitative indexes for precision seeder row unit SPC 6

Row unit type	Density [pl/ha]	Working speed [km/h]	A [%]	D [%]	M [%]	σ [-]	C [%]
S_1	48100	4	95.242	3.791	0.967	0.097	9.712
		6	94.473	3.172	2.355	0.101	10.187
		8	93.503	2.815	3.682	0.105	10.561
	49950	4	94.496	4.691	0.813	0.102	10.227
		6	94.141	3.875	1.984	0.107	10.743
		8	93.423	3.181	3.396	0.109	10.928
	51948	4	93.674	5.534	0.792	0.108	10.842
		6	93.412	4.124	2.464	0.111	11.143
		8	93.035	2.534	4.431	0.116	11.624

In table 2 are shown the qualitative indexes for precision seeder row unit SPF 6

Table 2 Qualitative indexes for precision seeder row unit SPF 6

Row unit type	Density [pl/ha]	Working speed [km/h]	<i>A</i> [%]	<i>D</i> [%]	<i>M</i> [%]	σ [-]	<i>C</i> [%]
S_2	48100	4	97.581	2.283	0.136	0.071	7.122
		6	97.238	1.843	0.919	0.073	7.345
		8	96.345	1.102	2.553	0.076	7.651
	49950	4	97.119	2.557	0.324	0.074	7.487
		6	96.042	1.976	1.982	0.078	7.824
		8	94.271	1.247	4.482	0.086	8.623
	51948	4	96.740	2.893	0.367	0.079	7.952
		6	95.215	2.548	2.237	0.086	8.647
		8	93.613	2.135	4.252	0.091	9.142

In table 3 are shown the qualitative indexes for precision seeder row unit SEMA 6

Table 3 Qualitative indexes for precision seeder row unit SEMA 6

Row unit type	Density [pl/ha]	Working speed [km/h]	<i>A</i> [%]	<i>D</i> [%]	<i>M</i> [%]	σ [-]	<i>C</i> [%]
S_3	48100	4	96.266	2.982	0.752	0.085	8.589
		6	95.543	2.636	1.821	0.087	8.877
		8	94.992	1.943	3.065	0.092	9.255
	49950	4	95.374	3.341	1.285	0.088	8.828
		6	94.664	2.848	2.488	0.094	9.411
		8	93.592	1.785	4.623	0.099	9.965
	51948	4	95.066	4.287	0.647	0.089	8.997
		6	93.675	3.951	2.374	0.093	9.337
		8	93.286	2.177	4.537	0.097	9.791

CONCLUSIONS

Analyzing the results obtained:

- sowing precision is higher for row units S_2 and S_3 (endowed with centralized transmission of seeds distributing devices) comparing to row unit S_1 (endowed with individual transmission of seeds distributing device), caused by skidding;
- sowing precision decreases along with speed and plants density growing;
- at low speed (4 km/h) index $D > M$ which indicates the apparition of doubles, and at higher speed (8 km/h) it is found that $D < M$ which indicates the apparition of missing pockets. This phenomenon appears because of the fact that the diameter of distributing disc hole is limited by the minimum size of seed to be sown. If the grain is not big enough, the process of catching the seeds through holes and maintaining them during the disc rotation is unsatisfactory, the number of holes which do not take the seeds increasing, namely those of big size and mass. In case of a too much pressure difference, the process of catching the seeds in holes is worsening by increasing the frequency of holes which take two or more seeds, phenomenon mostly emphasized in case of small dimension and mass seeds.
- indexes A (supplying quality index), D (index of doubles), M (index of missing seeds), σ (theoretical deviation), C (variation coefficient) are clearest comparison criteria between tests performed in different working conditions or equipment tested in the same working conditions;
- quality indexes displayed on stand SPS-3 constitute appreciation criteria of tested machines behavior, eventually decision criteria for improving the constructive solutions adopted.

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REZULTATI SETVE KUKURUZA TWIN – ROW SEJALICOM U REGIONU SOMBORA

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SAŽETAK

Kukuruz je najzastupljenija biljna vrsta u poljoprivrednoj proizvodnji u AP Vojvodini. U strukturi setve u 2013 godini kukuruz se gajio na ukupno 684081 ha, sa prosečnim prinosom od 5780 kg/ha. U zapadno – bačkom regionu kukuruz se gajio na 61.106 ha, što predstavlja 8,93 % ukupnih površina u AP Vojvodini sa prosečnim prinosom od 6.071 kg/ha. Po podacima PSS Sombor kukuruz u 2014. godini zauzima 65.189 ha od ukupno 149.800 ha obradivih površina u zapadno – bačkom okrugu ili 43,5 % od ukupnih obradivih površina. Postavljanjem oglada sa setvom kukuruza na klasičan način i setvom Twin-Row sejalicom zacrtano je da se dođe do rezultata koji su ostvareni ovakvim načinom setve na našem regionu.

Ogledi, zamišljeni od strane zastupnika sejalice za Twin-Row setvu, provedeni su u Doroslovu na RPG Holo, gde je sejan merkantilni kukuruz i u ZZ Karavukovo, gde je sejan postrni kukuruz za silažu. Umesto klasične setve, kada se kukuruz seje na međuredno rastojanje od 70 cm, ovim načinom se ostvaruje setva kukuruza na međurednom rastojanju od 29,5" - 75 cm. U svakom redu seju se dva reda na rastojanju od 20 cm, čime se međuredno rastojanje smanjuje na 55 cm.

Rezultati dobijeni u ogledu uporednim ispitivanjem setve kukuruza klasičnom i Twin – Row sejalicom pokazuju da se setvom u duple redove ostvaruje nešto veći prinos, pogotovo u setvi postrnog silažnog kukuruza, ali bi ovi rezultati trebalo da se provere ponavljanjem oglada.

Ključne reči: kukuruz, setva, Twin Row sejalice, prinos

UVOD

Rad predstavlja jednogodišnje rezultate uporedne setve kukuruza na klasičnoj obradi i setvi i setvi sa Twin-Row sejalicom i setvi postrnog silažnog kukuruza Twin-Row sejalicom bez prethodne obrade. Ogled na klasičnoj obradi u Doroslovu izveden je na parceli

nepravilnog oblika površine 9,27 ha na predusevu soja, a ogled u direktnoj setvi u Karavukovu na površini od 25 ha na predusevu ječam. Tehnologija proizvodnje kukuruza: distribucija mineralnih hraniva N:P:K (15:15:15) u količini 350 kg/ha, osnovna obrada plugom na 25cm dubine, zatvaranje brazde, distribucija mineralnog hraniva u količini 350 kg/ha Urea, pa predsetvena obrada – kompaktor i setva. Poravnatost parcele u porečnom i podužnom pravcu nije utvrđivana, ali je primenom oruđa za predsetvenu pripremu setveni sloj bio sitno orašaste strukture, a sabijenost parcele dobra. Merenja na ogledu u Doroslovu vršena su na delovima parcele od po 0,5 ha po ispitivanoj varijanti, gde je utvrđivana i brzina setve i vršena sva neophodna merenja vezana za ocenu kvaliteta setve, a u Karavukovu na delu gde je utvrđivana radna brzina sejalice. Sejan je hibrid kukuruza iz FAO grupe 500 sa preporučenim sklopom od 72 -75000 bilj/ha. Setva je u Doroslovu obavljena 12.04., zaštita useva od korova 19.05., merenje su obavljena 20.05., a ubiranje ogleda obavljeno je 08.10.2014 godine. Setva ogleda u Karavukovu obavljena je na predusevu ječam uz istovremeno unošenje mineralnog hraniva Urea u količini 250kg/ha 23.06., zaštita useva 12.07., merenja su obavljena 14.07., a ubiranje 01.10.2014 godine. Ogled je izveden bez navodnjavanja, iako je parcela pod sistemom za navodnjavanje. Ukupne padavine u toku vegetacije merene su na automatskoj mernoj stanici udaljenoj 1km od parcele na kojoj je izveden ogled i iznosile su 326,5 mm vodenog taloga.

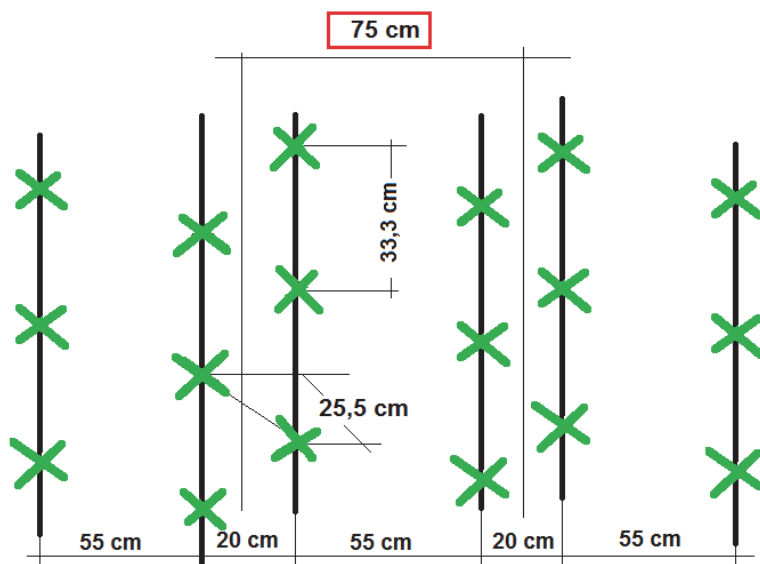
Po literaturnim podacima *Twin-Row* setva se javila ranih devedesetih godina u SAD kao želja da se poveća broj biljaka po ha i na taj način ostvari veći prinos. Tokom godina ispitivanja razvijen je i novi sisten setve u trake. Više podataka o vremenu nastanka ovog sistema setve, njegovom razvoju i rezultatima ogleda koji su vođeni možete saznati na <http://www.twin-row.com>. Danas u svetu ima velik broj proizvođača sejalice za ovaj način setve koji se preporučuje za tzv “vertikalnu obradu” kako iz SAD tako i EU. Po literaturi u SAD setva *Twin-Row* sejalicama ima prednosti u odnosu na klasičnu setvu kukuruza jer se povećava sklop biljaka po ha, takve biljke bolje koriste svetlost i vegetacioni prostor, koren biljaka kukuruza manje konkuriše jedan drugom, fiziološki izgled biljaka se poboljšava i ostvaruje se nešto veći prinos po ha (Kevin Jarek, Joe Lauer, 2011; Anonim 2010, Mariana Robles, Ignacio A. Ciampitti, and Tony J. Vyn, 2012; Anonim 2010). Pojedini autori navode da u njihovim radovima nema signifikantnih razlika u visini prinosa između kukuruza sejanog na klasično rastojanje redova i onaj sejan *Twin-Row* sejalicama (Greg Roth, Scott Harkcom, Shaun Heinbaugh and Mark Antle, 2002; Clarke McGrath, Jeff Butler, Bernie Havlovic 2002; Brian P. Jones, 2007). U EU rađen je velik broj ogleda od 2003, a naročito visok intenzitet ovih ogleda izveden je 2012 i 2013 godine. Rezultati evropskih autora pokazuju slične rezultate grupi američkih autora koji tvrde da postoji delimično povećanje prinosa (F.J. García Ramos, A. Boné Garasa, M. Vidal Cortés, 2014; Jócsák Attila, 2014; Anonim 2014; Jan-Martin Küper 2014; Carlos Martín Esteban, Luis Miguel Iribarren Martínez 2013; Miguel Gutiérrez López, José Mula Acosta 2013, Massimo Blandino, Amedeo Reyneri, Giulio Testa, 2013; Anonim 2012, Anonim 2010; Ing. Marek Jakubec 2010). Tokom 2013 godine u RS izveden je veći broj ogleda u setvi kukuruza, soje i suncokreta *Twin-Row* sejalicama.

Cilj ovog rada je da se u proizvodnim uslovima AP Vojvodine, na teritoriji Zapadno – bačkog okruga, provere postignuti rezultati u proizvodnji kada se za setvu kukuruza koriste *Twin-Row* sejalice. U okviru istraživanja posebna pažnja usmerena je na rezultate ostvarene

u rasporedu semena u redu, ostvarene dubine setve, a kao krajni rezultat, broj biljaka u ubiranju i visina dostignutog prinosa.

MATERIJAL I METODE

Na parceli u Doroslovu sejan je hibrid kukuruza iz FAO gupe 500. Setva kukuruza na međuredno rastojanje od 70 cm izvedena je sejalicom PSK 6 – OLT Osijek u agregatu s traktorom Casse 120. *Twin-Row* setva izvedena je osmorednom sejalicom Great Plains Yield-Pro YP825AR u agregatu s traktorom Casse IH MAXXUM 140 na međuredni razmak 29,5" – 75 cm. Brzina setve za jednu i drugu sejalicu utvrđivana je na deonici od 50 metara uz merenje vremena za pređeni put. Utvrđena je brzina setve za sejalicu PSK 6 od 8,12 km/h, a za sejalicu Great Plains brzina setve je iznosila 8,62 km/h, što je potvrđeno i praćenjem trenutnih brzina kretanja u kabini traktora. Sejalica za klasičnu setvu podešena je po preporuci proizvođača semena na rastojanje u redu od 19 cm, što odgovara teoretskom sklopu od 74 000 zrna/ha. Setva sejalicom Great Plains obavljena je na teoretski sklop od 80 045 isejanih zrna, što odgovara rastojanju semena u redu od 33,3 cm u svakom od duplih redova, što znači da je na ovaj način posejano 6000 semena/ha više nego kod klasične setve. Izgled setve *Twin-Row* sejalice dat je na slici 1.



Sl. 1 Shema setve *Twin-Row* sejalice

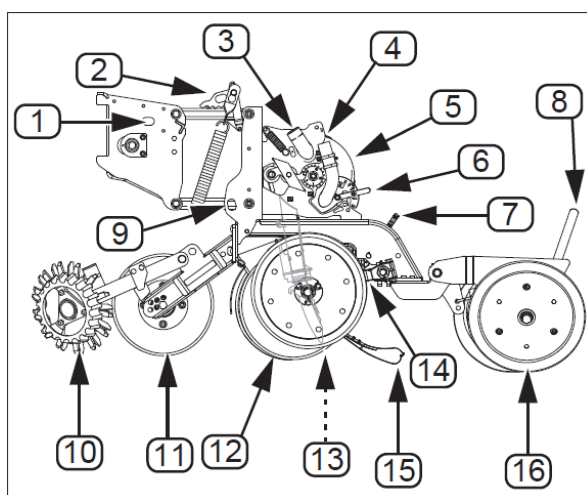
Fig. 1 Scheme of sowing by using *Twin-Row* planter

Utvrđivanje kvaliteta setve obavljeno je po DLG metodu nakon nicanja kukuruza kada je kukuruz bio u fazi 10 prema BBCH skali. Zaštita kukuruza izvedena je isti dan uz korišćenje identičnih preparata. Ubiranje je obavljeno kombajnom sa šestorednim adapterom za kukuruz, nakon čega je merenjem utvrđen ostvareni prinos po ispitivanim varijantama. Za

utvrđene prinose merena je vlaga zrna i primese po metodu SRPS(1). Po obavljenom ubiranju kukuruza brojanjem stabljika u tri ponavljanja utvrđen je i sklop biljaka za obe ispitivane varijante setve.

Ogled u Karavukovu sa direktnom setvom postrnog silažnog kukuruza izveden je tako što je setva izvedena pri preporučenoj brzini. Brzina kretanja agregata Great Plains Yield-Pro YP825AR + traktor Casse IH MAXXUM 140 je utvrđivana na deonici od 50 m, i proveravana u kabini traktora na displeju za kontrolu setve sejalice. Zadati razmaku u setvi bio je 29,7 cm, što znači da je predviđeni isejani broj zrna trebao da iznosi 89 719 zrna/ha. Treiranje pesticidima obavljeno je pre utvrđivanja drugih pokazatelja. Utvrđivanje kvaliteta setve obavljeno je po DLG metodu nakon nicanja kukuruza kada je kukuruz bio u fazi10 prema BBCH skali.

Merenje prinosa obavljano je na vagi udaljenoj od parcele više od 6 km, tako da je pre podne i popodne merena težina po jedne prosečne garnitura prikolica – koje su bile identične. Nakon završetka ubiranja na bazi odvaga i ukupnog broja garnitura utvrđen je ukupni prinos silaže.



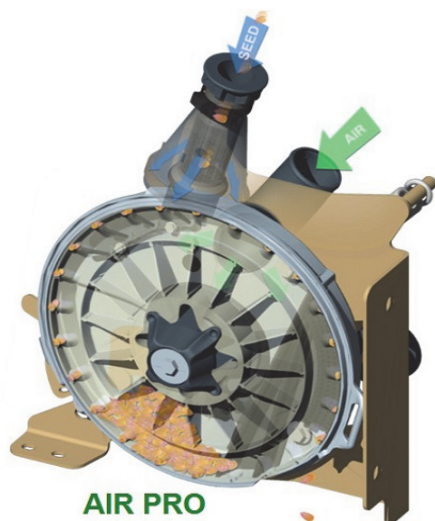
Sl. 2 Izgled setvene sekcije sejalice

Fig. 2 Scheme of Row Unit

Vučena sejalica Great Plains Yield-Pro YP825AR je namenjena za setvu u klasičnim sistemima obrade, kao i u konzervacijskim sistemima obrade, a može se koristiti i u direktnoj setvi u lakšim uslovima. Robusne je konstrukcije, koristi sopstvenu konstrukciju za rad i transport. Vrlo lako se sklapa i za kratko vreme, putem hidrauličnog mehanizma, se postavlja u radni položaj. Radi na principu nadpritiska, vrlo lako se vrši zamena diskova za određivanje rasporeda zrna u redu, a postavljanjem odgovarajućeg prenosnog odnosa bira se željeni sklop biljaka po ha. Izgled setvene sekcije prikazan je na sl. 2. Detalji sa slike 2. su: 1– zaključavanje i puštanje sejalice u radni položaj, 2– podešavanje radnog pritiska sekcije, 3– ulaz vazduha, 4– dovod semena, 5– disk za setvu različitih biljnih vrsta, 6–

kontrola nivoa količine semena u disku, 7– ručica za podešavanje dubine setve, 8– podešavanje pritiska i ugla nagaznih točkova sejalice, 9– kontrola radnog položaja sekcije, 10– opciona oprema za uklanjanje žetvenih ostataka, 11– diskovi za prosecanje brazdice za seme, 12– dupli diskovi otvarači brazdice za seme, 13– ulagač semena sa senzorom, 14– opciono poništavači – nisu prikazani, 15– pritiskivači semena, 16– pritiskujući točkovi za zatvaranje brazdice.

Potrebna minimalna snaga traktora za rad sa sejalicom iznosi 92 kW. Zapremina svakog od rezervoara za seme iznosi 1,6 bushela, odnosno 35,2 l na koji se dodaje maksimalno 60 ml lubrikanta. Izbor diskova vrši se prema vrsti i krupnoći semena koja će se sejati, kao i prema preporučenoj radnoj brzini sejalice. Princip rada setvenog aparata prikazan je na sl. 3.



Sl. 3 Setveni aparat sejalice *Twin-Row*
Fig. 3 Sowing apparatus *Twin-Row*

Uz rezervoare za semena sejalice je opremljena i depozitorima za mineralna hraniva koja se mogu unositi istovremeno sa setvom. Opcionalno moguće je koristiti tečna ili granulirana mineralna hraniva. Pritisak setvene sekcije moguće je regulisati za svaku sekciju posebno u rasponu od 140 do 250 kg po sekciji čime se omogućava fino podešavanje pritiska naročito setvenih sekcija koje rade na tragovima traktora. Diskovi otvarači brazde su tzv “turbo” izvedbe čime se povećava dubina ulaska diskova u zemljište, kvalitet rada i bolje presecanje žetvenih ostataka. Položaj diskova podesiv je u šest položaja. Rastojanje semena u redu podešava se za svaki red posebno, kako bi se dobio što povoljniji naizmenični raspored biljaka tokom vegetacije. Pre punjenja setvenog aparata neophodno je izvršiti tretiranje semena lubrikantom (talkom), kako bi se pospešilo i olakšalo kretanje semena kroz setveni aparat. Podešavanje sejalice za rad, promena setvenog diska – doboša, izbor odgovarajućeg rasporeda semena u redu se obavlja lako i za kratko vreme.

REZULTATI I DISKUSIJA

Pokazatelji koji su ostvareni u setvi kukuruza klasičnom i Twin-Row sejalicom prikazani su u tabeli 1.

Tab. 1 Pokazatelji kvaliteta rada ispitivanih sejalice (mereno posle nicanja)

Tab. 1 Quality indicators of work (measured after emergence)

Pokazatelji Indicators	Jedinica Unit	Tip sejalice Type of planter	
		PSK – 6	<i>Twin-Row</i> Great Plains
Brzina kretanja Working speed	km/h	8,12	8,62
Broj merenja Number of measurements	-	72	72
Broj redova Number of rows	-	6	8 duplih 8 double
Zadato rastojanje Theoretical space	mm	190	333
Ostvareno rastojanje Achieved space	mm	195,2	355,8
Standardna devijacija Standard deviation	mm	48,9	110,74
Koeficijent varijacije Coefficient of variation	%	25,06	32,89
Koeficijent preciznosti Coefficient of precision	%	53,6	38,6
Dubina setve Seeding depth	mm	5,35	6,24
Dupla mesta < 0,5 Double spaces	%	4,86	2,6
Na zadatom rastojanju >0,5<1,5 Places with distance>0.5 <1.5	%	91,67	91,42
Prazna mesta > 1,5 Empty spaces	%	3,47	5,98
Broj biljaka u ubiranju The number of plants in harvest	biljaka/ha plants/ha	70333	77650

Brzina kretanja sejalice bila je približno identična, ali su ostvareni različiti pokazatelji kvaliteta setve. Prosečno ostvareno rastojanje kod sejalice PSK 6 pokazalo je da je to svega

5,2 mm od zadatog, ali kad pogledamo standardnu devijaciju, koja nam pokazuje da je prosečno odstupnje od zadatog rastojanja 48,9 mm jasno je da sejalice nije dostigla kvalitetan raspored semena u redu. To nam potvrđuju i vrednosti koeficijenta varijacije od 25,06 % i činjenica da koeficijent preciznosti iznosi 53,6 %. Pokazatelji kvaliteta rada sejalice Great Plains Yield-Pro YP825AR (*Twin-Row*) imaju pokazatelje koji su još manje kvalitetni. Ostvareno prosečno rastojanje veće je od očekivanog – teoretskog za 22,8 mm, a kada se pogleda standardna devijacija, od 110,74 mm, onda njena vrednost indikativno pokazuje da je ova sejalice osetljiva na kvalitet i kalibraciju semena koja se koristi u setvi. Ovako visoka vrednost može se tumačiti i tako da nije izabran odgovarajući disk – doboš za setvu. Uz ovako visoku standardnu devijaciju, jasno je da koeficijent varijacije nije mogao imati nižu vrednost od 32,9 %. I jedna i druga sejalice pokazale su nizak procenat semena na zadatom mestu PSK 6 – 91,7 %, a sejalice Great Plains Yield-Pro YP825AR 91,4 %. Ovakav rezultat pokazuje nam da podešavanju sejalice treba posvetiti veliku pažnju.

Sejalice PSK 6 imala je veći procenat duplih mesta (4,86), a manji procenat praznih mesta (3,5) od sejalice Great Plains Yield-Pro YP825AR (*Twin-Row*), koja je ostvarila 2,6 % duplih i 6,0 % praznih mesta u setvi. Broj biljaka koji je utvrđen u ubiranju pokazuje da je tokom vegetacije došlo do smanjenja predviđenog sklopa kod sejalice PSK 6 sa teoretskih 74000 na 70333 biljaka/ha. Kod sejalice Great Plains Yield-Pro YP825AR (*Twin-Row*), broj biljaka prilikom ubiranja smanjen je sa teoretskih 80045 na utvrđenih 77650 biljaka/ha. Obzirom da nije bilo nikakve međuredne obrade na parceli, pretpostavljamo da je do umanjenja sklopa i kod jedne i druge ispitivane varijante došlo delovanjem prirodnih i klimatskih činilaca. Tretiranje kukuruza protiv štetnika – insekata iz roda *Ostrinia nubilalis* i *Helikoverpa armigera* nije vršeno.

Ostvareni rezultati u proizvodnji pokazani su u tabeli 2.

Tab. 2 Ostvareni prinosi kg/ha

Tab. 2 Obtained yield kg/ha

Pokazatelji Indicators	Jedinica Unit	Tip sejalice Type of planter	
		PSK – 6	Twin-Row Great Plains
Ubrana površina Harvested area	ha	0,47	0,47
Naturalni prinos Natural yield	kg	7420	7656
Sadržaj vlage Moisture content	%	23,81	23,12
Primese Impurities	%	2,2	2,7
Prinos sa 14 % vlage Yield by 14 % of MC	kg/ha	14102	14562

Ubiranje useva na oglednoj parceli obavljeno je 08.10.2014 godine univerzalnim samohodnim kombajnom sa šestorednim kukuruznim adapterom. Upravljanje kombajnom bilo je otežano prilikom kombajniranja parcele s *Twin-Row* setvom, jer je adapter bio predviđen za međuredno rastojanje 70 cm, pa se moralo voziti manjom brzinom. Radi lakšeg okretanja kombajna ivični delovi oglednih parcela su okombajnirani te je stvarna veličina oglednih parcela bila 0,47 ha po ispitivanoj varijanti. Ostvareni su vrhunski prinosi za obe ispitivane varijante. Prinos u *Twin-Row* setvi veći je od prinosa ostvarenog u klasičnoj setvi 14.102 kg/ha za 3,26 % i iznosio je 14.562 kg/ha. Najveći uticaj na visinu prinosa u ovoj godini imali su klimatski činioci. Utvrđene primese u obe ispitivane varijante su niže od standardom predviđenih, pa nije vršen obračun naturalnog prinosa koji obuhvata primese.

Tab. 3 Pokazatelji kvaliteta rada ispitivane sejalice (mereno posle nicanja)

Tab. 3 Indicators of sowing quality (measured after emergence)

Pokazatelji Indicators	Jedinica Unit	Great Plains Twin-Row
Brzina kretanja Working speed	km/h	9,82
Broj merenja Number of measurements	-	72
Broj redova Number of rows	-	8 duplih 8 double
Zadato rastojanje Theoretical space	mm	297
Ostvareno rastojanje Achieved space	mm	318,9
Standardna devijacija Standard deviation	mm	141,8
Koeficijent varijacije Coefficient of variation	%	44,59
Koeficijent preciznosti Coefficient of precision	%	32.16
Dubina setve Seeding depth	mm	3,64 (0 – 6,1)*
Dupla mesta < 0,5 Double spaces	%	2,21
Na zadatom rastojanju >0,5<1,5 Places with distance >0.5 <1.5	%	87,38
Prazna mesta > 1,5 Empty spaces	%	10,41
Broj biljaka u ubiranju Number of plants in harvest	biljaka/ha plants/ha	77301

Nakon jednogodišnjeg oglada, rezultati dobijeni poređenjem dve ispitivane varijante ukazuju na to da ispitivanja treba produžiti, jer utvrđeno povećanje prinosa od 3,26 % u ovako klimatski pogodnoj godini za kukuruz nije relevantno za donošenje konačnih odluka o opravdanosti uvođenja ovakvog načina setve kukuruza u Zapadno - bačkom regionu.

Setva posrtnog silažnog kukuruza obavljena je u ZZ Karavukovo u Karavukovu. Pokazatelji kvaliteta rada dati su u tabeli 3.

Predusev je bio ječam, izvršeno je uništavanje žetvenih ostataka, a zatim direkta setva sa istovremenim unošenjem mineralnih hraniva sejalicom Great Plains Yield-Pro YP825AR (*Twin-Row*). Uneta količina hraniva Urea iznosila je 250 kg/ha. Setva je obavljena na rastojanje semena u redu od 297 mm, što bi trebalo da obezbedi teoretski broj 89719 biljaka/ha. Karakteristika setve je vrlo neujednačena dubina setve. Prosečno utvrđena dubina setve je 3,6 cm, sa velikim brojem semena koja su deponovana na manju dubinu od prosečne. Veći broj semena ostao je na površini, u dubini brazdice, što je imalo za posledicu značajno smanjenje broja biljaka po hektaru pri ubiraju silaže. Umanjenje sklopa biljaka je bilo za 13,8 % u odnosu na teoretski broj biljaka u setvi, odnosno za 12.400, ne samo zbog slabijeg kvaliteta setve već i zbog kasnijih velikih šteta od divljači. Zbog neujednačene dubine setve primetno je bilo da su pojedine biljke kasnile po fenofazama razvoja, što bi imalo velike posledice po prinos da je u pitanju bila proizvodnja merkantilnog kukuruza.

Ostvareno prosečno rastojanje semena u redu od 318,9 mm, veće je od zadatog za 21,9 mm, a o kvalitetu setve govore izuzetno visoke vrednosti standardne devijacije od čak 142 mm i koeficijent varijacije od 44,6 %. Visok procenat duplih mesta od 2,21 % i izuzetno visok procenat praznih mesta od 10,4 % u setvi govore nam da je sejalice ostvarila vrlo loše pokazatelje kvaliteta rada u ovom načinu setve. Zabeležen je raspored u okviru zadatog razmaka semena od svega 87,38 %, što govori da u direktnoj setvi sejalice nije pokazala zadovoljavajuće rezultate. Zbog izrazito obimnih padavina, 3267 mm u toku vegetacije od čega 86 mm dva dana posle setve, ostvaren je visok prinos od 5,3 t/ha zelene mase. Koliko je bilo mase, i koliko je međuredno rastojanje u setvi *Twin-Row* sejalicom, najrečitije govori i to da je silažni kombajn istovremeno ubirao po pet redova kukuruza, a ne šest za koliko je bio predviđen.

ZAKLJUČCI

Uskladu sa uporednim rezultatima setve kukuruza na klasičan način i setvom *Twin-Row* sejalicom prikupljenim poljskim merenjima utvrđeno je da je:

1. Ostvareno prosečno rastojanje semena u redu kod obe ispitivane varijante veće je od očekivanog.
2. Broj biljaka koji je utvrđen u ubiranju pokazuje da je tokom vegetacije došlo do smanjenja predviđenog sklopa kod obe sejalice.
3. I jedna i druga sejalice pokazale su nizak procenat semena raspoređenog na zadatom mestu, odnosno u zoni prihvatljivog ili dozvoljenog odstupanja, tek nešto iznad 91 %, uz niske koeficijente preciznosti od 53,6 % za sejalicu PSK i 38,6 % za sejalicu Great Plains Yield-Pro YP825AR.

4. Ostvaren je visok prinos kukuruza u obe posmatrane varijante. Prinos u Twin-Row setvi veći je od prinosa ostvarenog u klasičnoj setvi za 3,26% i iznosio je 14.560 kg/ha. Ostvareni prinos u Twin-Row setvi je u okviru statističke greške, dakle, odstupanja nema.
5. U setvi postnog silažnog kukuruza, u direktnoj setvi, i pored izuzetno nepovoljnih rezultata ostvarenih u poljskom ispitivanju ostvaren je visok prinos od 5,3 t/ha zelene mase.
6. Nakon jednogodišnjeg oglada, rezultati dobijeni poređenjem dve ispitivane varijante ukazuju na to da ispitivanja treba produžiti.
7. Ako se ostvari primena setve kukuruza u Twin – Row sistemu otvara se i niz drugih pitanja vezanih za ovaj način setve, kao što su: najpovoljniji sistem obrade za setvu u Twin-Row sistemu, vrsta i način upotrebe mineralnih hraniva u ovakvom načinu setve, izbor hibrida i izbor najpovoljnijih gustina setve za izabrane hibride u Zapadno – bačkom regionu. U daljnjim ispitivanjima trebalo bi da se provere efekti rada ovakve sejalice.

RESULTS OF CORN SOWING BY USING TWIN – ROW PLANTER IN SOMBOR REGION

SUMMARY

Corn is the most common crop in agricultural production in the Autonomous Province of Vojvodina. The structure of sowing in 2013 shown that corn is grown to a total of about 684,000ha, with an average yield of 5,780 kg/ha. In the West - Backa Region maize is cultivated on 61,106 ha, representing 8.9 % of the total area in the Autonomous Province of Vojvodina with an average yield of 6071kg/ha. According to figures from the PSS Sombor corn in 2014, occupying 65,189 ha of the total 149,800 hectares of arable land in the West - Backa, or 43.5 % of the total arable land. The experiment with sowing corn in the conventional way and Twin-Row planter was intended to get the results achieved with this type of planting in our region.

The experiments, designed by the representative of Twin-Row planter, were derived in the Doroslovo, on the RPG Holo, where commercial maize sown, and in ZZ Karavukovo where stubble sown corn silage. Instead of the classic sowing, when the corn is sown at row spacing of 70 cm, this method is achieved sowing corn at a distance of 29.5" – 75 cm respectively. In each row sowing two rows at a distance of 20 cm, thereby inter row spacing is reduced to 55 cm. The results obtained in the experiment comparative examination of sowing maize classical and Twin-Row planter indicate that planting in double rows achieves a slightly higher yield, especially in sowing stubble corn silage, but these results should be verified by repeating the experiment.

Key words: corn, sowing, Twin-Row planter, yield.

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TESTING EXPERIMENTAL MODEL OF DRILL FOR GRASSLANDS REGENERATION

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SUMMARY

Grasslands are lands covered with permanent herbaceous vegetation composed of species belonging to several families of plants, especially grasses and perennial legumes, used as fodder or grazing.

The current trend of worldwide research and in Europe in terms of permanent grassland, in conjunction with forecasts of global warming will affect climate and agro-forestry-pastoral background, is to maintain phytocenotic biodiversity of them.

Grassland degradation is caused by the changes taking place in the living conditions of plants, vegetation structure, due, in large part, to climate change and their inappropriate management. When these changes are accompanied by reduced production or worsening of its quality, it is estimated that degrade the grassland.

Harmonization assign factors to obtain high yields with environmental protection and economic efficiency in maintaining the grasslands, requires a complex scientific approach, targeting and differentiated technology application, adapted to the climatic and vegetation features based on scientific management, rational balanced, respecting the environment and biodiversity, using appropriate technical equipment.

In this paper, experimental research consisted of work qualitative and energy indices determination of an innovative technical equipment performing regeneration of grasslands by narrow strips of soil processing and sowing directly into the grassy carpet of a mixture of herbs or even a single species, maintaining full or a certain percentage of existing vegetation. Tests were conducted in an experimental field consisting of a permanent grassland with low herbaceous

vegetation cover, with a poor floristic composition and low percentage of clover, alfalfa and lolium.

The experimental results obtained in this paper are used by farmers in the selection of technical equipment to meet the quality requirements of the EU market for rational exploitation and regeneration of degraded permanent grassland.

Key words: *grasslands, regeneration, technical equipment*

INTRODUCTION

As provided in par. (1) of Art. 6 of Regulation (EC) no. 73/2009, which was published in the EU Official Journal, permanent grasslands are agricultural areas of pastures and hayfields, natural or cultured, used for the production of grasses or other herbaceous forage, which included at least five years in the system of rotation and which are used for grazing and feed production, observing good agricultural and environmental conditions [16].

In Romania, the Government E. O. no. 34/2013 [14], gives a new regulation concerning the organization, administration and operation of permanent grassland in that, forces all users to take all necessary measures for their maintenance, maintaining the category of use.

Good agricultural and environmental practices and legal requirements management are mandatory for all farmers in Romania, so grasslands overseeding should be done only with seed families perennial herbaceous forage grasses and legumes or mixtures thereof, and overseeding grasslands contained in protected areas should be made only with seed species adapted to the climate of those protected areas [15].

Grasslands International Congress defines grassland as exploitable farmland, used for crop years or permanently, grass and other forage crops that are traditionally on natural pastures and hayfields or that are included in specific mixtures for seeding and overseeding, the families of grasses and legumes used as feed herbivores, on calculating the production, nutritional value of grassland and grazing capacity [1].

In 2050 for feeding of approx. 10 billion people of the world who will live in cities, will require increasing the amount of food to approx. 70% of today [3].

Since 2008, when extreme weather conditions manifested by floods and drought, fragile food systems, sensitivity to the vagaries of trade and price fluctuations have been to the fore, the role of agriculture, including research and development efforts form the basis of back on the agenda at global, regional and national levels as an essential component of food security [13].

Grasslands are ecosystems that respond fastest to the variability of rainfall, increasing aridity and persistent droughts that are expected to take place in the coming years especially for the most part of Africa, Southern Europe and the Middle East, America, Australia and Southeast Asia. A number of these regions (fig. 1) have a large proportion of land covered by grassland. The colour scale indicates the percentage cover by grazing land in each grid cell. Circled in red, are areas with a significant increased number of consecutive dry days in 2080-2100 compared to 1980-2000 [6].



Figure 1 Drought hot spots in global grazing lands by 2080-2100 [6]

Forage grass is the most consumed feed in the world (2.3 Gt in 2000), representing 48 % of all biomass consumed by livestock; of this, 1.1 Gt are used in mixed systems and 0.6 Gt in grazing-only systems [9].

The multifunctionality of permanent grasslands in Romania is provided by the complexity of utilization of this land patrimony, like: food source for animals, performance of connected economic activities, life habitat for animals, great diversity of plant species and a genetic germplasm fund, important factor for soil protection (at the most difficult altitudes), landscape and energetic importance [5].

Because a long period of time did not apply even the most basic grasslands maintenance measures, considering that you can get efficient production without technological inputs, now modern EU policies are formulated to solve problem of biodiversity decline and destruction of grassland landscapes and sensitive habitats in Europe [10].

Worldwide surveys were conducted to maintain phytocoenotic biodiversity of permanent grasslands, which have become increasingly degraded due to desertification, poor management of grazing, industrial development, pests and intensification of human activities in areas of pasture [8].

The research was conducted in time to understand the behaviour of grass growth by collecting daily data on minimum temperature, average and maximum rainfall, wind speed, humidity, radiation and pressure were used to calculate an index of monthly moisture, evapotranspiration [2], the amount of rainfall and number of days without rain [7]. Maintaining the balance of grasslands grassy carpet is an art which aims at knowledge of plants, nutrient and moisture requirements thereof and applying differentiated technologies, adapted to the climatic and vegetation peculiarities based on scientific management, rational and balanced, respecting the environment and biodiversity using appropriate technical equipment [11].

In Romania, the Research Institute for Grassland Brasov in 2002 has conducted research for the regeneration of degraded grassland with an over seeding machine, consisting of seeding sections mounted on a frame, fitted with triangular bracket on the tractor linkage, sections provided impeller disk rim, anchor coulter and two bunkers for seeds, the sections

are fastened to the frame sown by some deformable parallelograms, which together with rods with coil springs, press on parallelograms extension bars, thus ensuring uneven terrain copying each row [12].

METHODS

The machine, which was used in the experimental research presented in this paper, comprises milling sections equipped with active organs, housing and skate for depth adjustment and sowing sections provided with coulter, compacted wheel, adjustable screw sowing depth and seed tube to achieve uniform over seeding in narrow strips in a single pass, with a mixture of herbs, to restore their flora [4].

Determination of work qualitative indices was performed in the laboratory on a testing stand, and energy indices were determined in the field, on a plot consisting of a permanent grassland with low herbaceous vegetation cover, with a poor floristic composition and small percentage of clover, alfalfa and Lolium.

For seeds used in experiments were determined following physico-mechanical characteristics: degree of purity, weight of 1000 seeds, hectoliter mass and moisture. The measurements were carried out with precision of ± 0.1 grams with an electronic balance in 3 repetitions. The average values obtained are shown in Table 1.

Table 1 Physico-mechanical characteristics of seeds used in experiments

No.	Seed name	degree of purity %	weight of 1000 seeds g	hectoliter mass g/dm ³	moisture %
1.	Alfalfa	99.02	1.9185	80.63	9.52
2.	Clover	97.32	2.1382	78.05	8.88
3.	Lolium multiflorum	99.45	4.4066	39.82	1.95

Work qualitative indices to establish seeding rate were determined in the laboratory on a testing stand that provided to drive wheel a work speed equal by 4.17 km / h corresponding to movement tractor New Holland TCE 50 (engine 36.8 kW) in second gear speed.

Tests were carried out by turning the left wheel of 32 times, representing the movement of the machine on 100 m², positioning the pointer of the gearbox in the middle, the collection of seeds distributed by each distributor and them weighing. Each sample was performed in 3 repetitions.

Qualitative indices for determining the quality of work and energy indices were determined on grassland field, using the tractor New Holland TCE 50 and grasslands regeneration machine (fig. 2).

The main technical characteristics of machine for grasslands regeneration are: the number of section for soil processing in bands: 4 pcs; number of sections for sowing: 4 pcs; distance between bands worked and sown: 220 mm, working depth: 2...6 cm; maximum

seed rate: 10 kg/ha; weight: 493 kg. Grassland regeneration drill runs in a single pass seedbed preparation by performing bands, sowing a mixture of herbs or even a species inside bands and light compaction of the soil over the seed for a proper contact, in order to obtain a good germination.



Figure 2 Grassland regeneration drill and tractor New Holland TCE 50

Table 2 shows characteristics of the experimental field on which the experiments were carried out, with machine for grasslands regeneration and tractor New Holland TCE 50.

Table 2 The characteristics of the experimental field

No.	Characteristics	Experimental polygon
1.	Soil type	reddish brown forest
2.	Natural unevenness height anthills, cm	max. 8
3.	Degree of soil coverage with plants, %	78
4.	The average height of plants, cm	5.2
5.	Plant mass, g/m ²	50
6.	Soil humidity, %, in layer 0...10 cm	21.2

Tillage depth was determined by measuring the distance between the surface and the bottom of the furrow field left fallow for body work. Measurements were conducted in five points at intervals of 2 m between each other, for the working speed of 4.17 km / h.

Width tillage was determined in five different places by measuring distance from each stake marking the furrow wall, making the difference from the previous passage.

The seed depth incorporation is the distance measured from the ground level resulted from sowing work and the seeds horizon. The measurements were carried out in 3 repetitions, in 3 different parts of the plot (the ends and the middle).

RESULTS

Following **work qualitative indices** were determined on a testing stand that provided to drive wheel a work speed equal by 4.17 km / h.

The average amount on a seed box, N_m , was calculated according to the following equation:

$$N_m = \frac{\sum_{i=1}^8 N_i}{8}, \text{ g} \quad (1)$$

where N_i ($i = 1, \dots, 8$) is the amount obtained from each box in part.

Seed rate per hectare, N_s , was calculated according to the following equation:

$$N_s = \frac{N_m \times 8 \times 100}{1000}, \text{ kg/ha} \quad (2)$$

Seed rate stability, S_N , (<10%) was calculated according to the following equation:

$$S_N = \left[\frac{N_m - N_i}{N_n} \right] \times 100, \% < 10 \% \quad (3)$$

The uniformity of seed distribution on the working width, U , was calculated according to the following equation:

$$U = \frac{\sum_{i=1}^8 D_i}{N_n \times 8} \times 100, \% \quad (4)$$

where D_i ($i = 1, \dots, 8$) was calculated according to the following equation:

$$D_i = N_m - N_i, \text{ g} \quad (5)$$

The degree of seeds damage, G_{vs} (<3 %), was calculated according to the following equation:

$$G_{vs} = \frac{M_{sv}}{M_{ts}} \times 100, \% \quad (6)$$

where M_{sv} - injured seed mass in g and M_{ts} - total sample mass in g were determined by weighing.

Table 3 presents the average values of the work quality indices determined in experiments in laboratory conditions on testing stand.

Table 3 The average values of the work quality indices determined on testing stand

Species name	Row no.	N_i , g	N_m , g	N_s , kg/ha	S_N , %	U , %	M_{SV} , g	M_{TS} , g	G_{VS} , %
Alfalfa	1	7.7			0.00				
	2	7.8			1.30				
	3	7.5			2.60				
	4	7.9			2.60				
	5	7.7	7.7	6.16	0.00	2.9	1.4	61.3	2.28
	6	7.3			2.60				
	7	7.5			3.90				
	8	7.9			1.30				
Clover	1	6.6			0.00				
	2	6.7			1.52				
	3	6.5			1.52				
	4	6.8			3.03				
	5	6.6	6.6	5.28	0.00	2.5	1.2	52.9	2.26
	6	6.5			1.52				
	7	6.5			1.52				
	8	6.7			1.52				
Lolium multiflorum	1	9.1			0.00				
	2	9.2			1.10				
	3	8.9			2.20				
	4	9.4			3.30				
	5	9.1	9.1	7.28	0.00	2.3	1.6	72.6	2.20
	6	8.9			2.20				
	7	8.8			3.30				
	8	9.2			1.10				

The following **qualitative indices** were determined on grassland field, using the tractor New Holland TCE 50 and drill for grasslands regeneration.

Average working depth on seedbed preparation, a_{mpg} was calculated according to the following equation:

$$a_{mpg} = \frac{\sum_{i=1}^n a_i}{n}, \text{ cm} \quad (7)$$

where a_i is the depth of tillage and n - number of measurements.

Average width of the strips milled, B_m , was calculated according to the following equation:

$$B_m = \frac{\sum_{i=1}^n B_i}{n}, \text{ cm} \quad (8)$$

where B_i is the width of tillage and n - number of measurements.

Average sowing depth, a_{ms} , was calculated according to the following equation:

$$a_{ms} = \frac{\sum_{i=1}^n a_i}{n}, \text{ mm} \quad (9)$$

where a_i is seed depth incorporation measured at a point i .

Table 4 presents the average values of the work quality indices determined on grassland field, using the tractor New Holland TCE 50 and machine for grasslands regeneration.

Table 4 The average values of the work quality indices determined on grassland field

Indices	Value
Average working depth on seedbed preparation a_{mpg} , cm	2.4
Average width of the strips milled B_m , cm	7.3
Average sowing depth a_{ms} , cm	2.3

The following **energetic indices** were determined on grassland field, using the tractor New Holland TCE 50 and machine for grasslands regeneration.

Effective working speed, v_l , was calculated according to the following equation:

$$v_l = \frac{3,6 \times s}{t}, \text{ km/h} \quad (10)$$

where t is the travel time for space s .

Wheel slip, δ , was calculated according to the following equation:

$$\delta = \frac{n_s \times n_g}{n_s} \times 100, \% \quad (11)$$

where n_s is the number of rotations of loaded drive wheel and n_g is the number of rotations of unloaded drive wheel.

Hourly fuel consumption, q , was calculated according to the following equation:

$$q = \frac{3,6 \times \Delta C}{t}, \text{ l/h} \quad (12)$$

where ΔC is the amount of fuel consumed during the test calculated according to the following equation:

$$\Delta C = V \times \rho, \text{ l} \quad (13)$$

where V is the volume of fuel recorded by the device, in cm^3 , ρ - density of fuel in kg/dm^3 (EURO DIESEL density at 15 °C is 0.845 kg/dm^3) and t - time test in s.

Hourly work rate at effective time, W_{ef} , was calculated according to the following equation:

$$W_{ef} = 0,1 \times B_l \times v_l, \text{ ha/h} \quad (14)$$

where B_l is the working width of drill in m and v_l - working speed in km / h.

Fuel consumption per hectare, Q , was calculated according to the following equation:

$$Q = \frac{q}{W_{ef}}, \text{ l/ha} \quad (15)$$

Table 5 presents the average values of the energetic quality indices determined on grassland field, using the tractor New Holland TCE 50 and machine for grasslands regeneration.

Table 5 The average values of the energetic quality indices determined on grassland field

Indices	Value
Effective working speed v_l , km/h	4.17
Wheel slip δ , %	2.90
Hourly fuel consumption q , l/h	10.36
Fuel consumption per hectare Q , l/ha	14.19
Hourly work rate at effective time W_{ef} , ha/h	0.73

Work qualitative and energy indices obtained in experimental research, within the framework of agro technical requirements on degraded grassland regeneration. For example, seed rate stability (S_N) is smaller than 10%, the degree of seeds damage (G_{vs}) is smaller than 3 % and fuel consumption per hectare (Q) is small (14.19 l/ha) for hourly working capacity at effective time of 0.73 ha/h.

CONCLUSIONS

Experimental researches in laboratory and field have allowed validation of technical and technological solutions of grasslands regeneration drill.

The experimental results obtained can be used by farmers in choosing the grasslands regeneration drill that meets quality requirements imposed by Code of Good Agricultural and Environmental Conditions (GAEC), established in European Union Council Regulation (EC) number 1782/2003.

ACKNOWLEDGEMENTS

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/134398.

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TESTING EXPERIMENTAL MODEL OF TRAILED WINDROWER

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SUMMARY

Forage harvesting on grassland and on cultivated land is a common operation from spring until late fall, aiming to ensure to animals the daily needs of food.

The quantity and quality of forage depends on the harvesting technology and equipment used for this purpose.

Depending on the technology of work adopted, forage plants can be collected, for low moisture silage after swath conditioning, at a moisture content of 50...55%, or allowed to dry until the moisture of approx. 20% and collected them to be stored as hay or bale of hay.

Given the need to increase the quality of life in long term and under pressure from increased demands of consumers of vegetable and animal agricultural products, S.C. MECANO FUC S.A. and INMA Bucharest have joined scientific researches, concerning rational exploitation technology of permanent or cultivated grassland, by realizing an innovative equipment for harvesting and conditioning forage, performing operations such as: mowing, conditioning and forming swaths on the field, to dry naturally.

In this paper, experimental research consisted in determining the operational and energetic qualitative indices of a windrower with oscillating mowing technology, sickle bar mower and rollers with two metal crushing rollers with helically bars, this windrower performing plants cutting, crushing and forming swaths.

The conditioning process reduces the drying process on the field, preserving the nutritional qualities of the forage, thus avoiding depreciation by leaving them on the soil for long time.

Experimental results obtained during experiments will be used to optimize the work process, targeting exceeding performances than those currently existing for the equipment in the same category, so that farmers could have access to an technical equipment for harvesting forage in grasslands and cultivated land,

which satisfies the requirements of adaptation techniques and technologies for the rational exploitation of grasslands, according to the global and regional climate change.

Key words: *forage, harvesting, conditioning, windrower*

INTRODUCTION

According to the research conducted by the American Farm Bureau Federation, it is considered that forage, which are influenced by plant characteristics and their natural growing environment, provides most of the nutrients in the nutrition of ruminants. [1].

From studies concerning the diversified foraging, in sufficient quantities and proportions required in comparison to ordinary food [2], there was a better performance of fattening/growing animals, and the use as forage of phytomass resource (grassland, fodder crops) was based on the useful yield of the crop, quality and ease of preservation.

From a technical point of view, main elements for evaluating the quality of fodder are the economic performance of the cattle breeders [3].

Within the context of global and regional climate change, it was imperative to find innovative solutions to adapt the techniques and technologies for the rational exploitation of grasslands, as research conducted in recent years have shown immense possibilities of increasing forage quality. The quantity and quality of fodder depends, among others, by the harvesting technology and equipment used for this purpose [3].

Harvesting should be done during the time that the plants contain the maximum amount of nutrients, namely in blooming stage - beginning of flowering. Cutting is recommended to be at a height of 4...6 cm from the ground in natural grasslands, according to the land levelling degree, to ensure an adequate quantity and purity of the forage and to ensure further development perennial plant until the next harvest. In some cases, the process can be combined with some classic treatments applicable to the plants in order to reduce the period of hay drying and to improve the storage conditions, such as: plant crushing; treatment with dried substances and treatment with urea solution. Plant crushing is a process in which the tissues of the stems are pressed and the epidermis is damaged, in order to increase the evaporation surface of the stems. Avoid thereby drying gap between stems and leaves, reducing this period at half [5], [6].

Research conducted in the past by INMA Bucharest on gathering forage left in furrow after harvesting with a tracked windrower, fitted with rotary disc cutter, showed that it is recommended that this operation be made humidity 50...55% for silage or humidity approx. 20% for storage in the form of bulk or round hay [4].

METHODS AND MATERIALS

To perform experimental research under field conditions in order to determine the qualitative, energetically and exploitation indicators, of this trailed windrower designed for forage harvesting and conditioning, with oscillating mowing technology, sickle bar mower, for rational exploitation of permanent grassland and cultivated land, has been used a middle power tractor, type U650M, 47.8 kW.

To operate the windrower, the tractor used in the researches was equipped with monoblock hydraulic mechanism, with automatic adjustment of power and position. The main technical characteristics of the tractor are: a maximum laden tractor mass (with cab): 3620 kg; minimum turning circle: 3.40 m; front track width: 1320...1970 mm; rear track width: 1400...2050 mm; distance between front and rear axles (wheelbase): 2430 mm; tractor height with cab is 2630 mm; tractor length: 4070 mm.

This trailed windrower (Fig.1) used in the experimental research presented in this paper, consists of a forage harvesting equipment, which mowing, conditioning and forming uniform swath on natural or cultivated grasslands, to natural drying. The windrower chassis with wheels can be attached to the tractor drawbar.



Figure 1 Trailed windrower for harvesting and conditioning fodder

Table 1 Main technical specifications of the windrower used in the research

Cutting device type	Oscillating mowing technology
PTO speed, min^{-1}	540
Overall width, m	2.7
Cutting height (adjustable), mm	50...90
Swath width, mm	900...1200
Number of crushing rollers, pcs	2
Upper crushing roll diameter, mm	170
Lower crushing roll diameter, mm	197
Mass, kg	1300

Testing under field conditions of the windrower, coupled to the tractor drawbar 47.8 kW, type U650M, and driven by their PTO shaft, were conducted on farmland in the area of S.C MECANO FUC S.A., in Vaslui County.

Measurement equipment used to determine the qualitative and energetic indices in the experimental field were:

- Mechanical chronometer;
- Electronic tachometer;
- Electronic balance;
- Apparatus to determine fuel consumption;
- Resistive strain gauge transducers (strain gauges);
- Digital Measuring System MGCplus data acquisition.

The indices of qualitative work which were determined are:

- The effective working width, m
- Cutting height (stubble), mm
- Working speed, km/h
- Crushing plant percentage, %
- Dimensions and mass of swaths:
- width, mm
- height, mm
- mass (at harvesting), kg/m.
- Material losses, %

Determination of traction strength was done using resistive strain gauge transducers mounted on the drawbar of the tractor unit and the data acquisition was done on a laptop that was connected to the digital measurement data acquisition MGCplus equipped with special software Cadman for acquisition and processing.

Also, were measured the rotational speed and torque at PTO tractor, used in experiments, unloaded and loaded in work.

Power transmitted through PTO was calculated with the equation:

$$P_p = M_p \times \omega_p, \text{ W} \quad (1)$$

where:

M_p is the torque transmitted by PTO shaft, in Nm.

ω_p - angular speed of PTO shaft, in rad/s.

Traction power was calculated with the equation:

$$P_{tr} = \frac{F_{tr} \times v_l}{3600}, \text{ kW} \quad (2)$$

where:

F_{tr} is the measured traction force at the drawbar;

v_l – working speed (for travel), in km/h.

Real power consumption was established by equation:

$$P = P_p + P_{tr}, \text{ kW} \quad (3)$$

Table 2 shows the conditions under which the tests were conducted to in order determine the qualitative, energetically and working indices, with the windrower powered by a tractor of 47.8 kW type U650M.

Table 2 Yield and other characteristics of alfalfa harvested with windrower powered by a tractor, model U650M

Specification	Alfalfa
Vegetable production , t/ha	16,560
Growing Year	First year
Vegetation stage	35 % blooming
Average height of the plants, mm	740
Moisture content of the forage, %	71.3
Plants per m ² , in pcs.	198

Table 3 Rotational speeds of the working devices of trailed windrower

Rotational speeds	min ⁻¹
PTO shaft	540
Output shaft of multiplier	809
Fixed crushing roller	635
Mobile crushing roller	744
Reel	60

RESULTS AND DISCUSSION

The percentage of crushing plant was calculated with the equation (4).

$$X = \left(1 - \frac{S_1}{S_2} \right) \times 100, \% \quad (4)$$

where:

S_1 is the average mass of uncrushed plants in the swath, kg;

S_2 - the average mass of crushed plants in the swath, kg

It was considered that crushed herb plant whose stem was strangled in at least two places.

Material losses was calculated using the following equation:

$$q = \frac{\delta}{S_2} \times 100, \% \quad (5)$$

where:

δ is the mass of the little leafs and plant fragments collected from the ground by removing the swath just after crushing [7].

Table 4 presents the average values of the work quality indices under field conditions.

Table 4 Work quality indices

Specification	Value
Effective working width, mm	2750
Cutting height (stubble), mm	60
Working speed, km/h	6.2
Percentage of crushing plants,%	85
Dimensions and mass of the swaths:	
- width, mm	0.8...1.8
- height, mm	17.5
- mass (at harvest), kg/m	cca. 4.2
Material losses, %	0.92

The analysis of data presented in Table 3 revealed that the effective working width represents about 95% of the constructive working width, cutting height of 60 mm is according to the real setup, optimum working speed of 6.2 km/h was suitable to gear II.R of the tractor of 47.8 kW. Material losses of 0.92% were caused by errors of the driving of the aggregate.

Table 5 presents the average values of energetic indices determined under field conditions with the windrower in aggregate with U650M tractor.

Table 5 Energetic indices under field conditions with the windrower in aggregate with U650M tractor

Parameter	Unloaded	Under load
Effective working speed (v_e), in km/h	-	6.2
Tractor engine speed in the aggregate, min^{-1}	1853	1813
PTO rotational speed of the tractor, min^{-1}	556	544
PTO effective torque, Nm	26.88...30.16	37.23...40.62
Real power consumption, kW	16.5	22.3

PTO real torque of the tractor required to acting the work devices, unloaded, varied between 26.88...30.16 daNm, resulting in an average power of 16.5 kW, and in working conditions has fluctuated between 37.23...40.62 daNm, resulting in an average power of 22.3 kW.

**Figure 2** Windrower trailed and powered by a tractor U650M during field experiments

Effective work rate (W_{ef}) was calculated with the equation:

$$W_{ef} = \frac{60U}{T_l}, \text{ ha/h} \quad (6)$$

where:

U is the quantity of work, in ha;

T_l – effective working time, in min.

Work rate by shift (W_{07}) was calculated with the equation (7).

$$W_{07} = \frac{60U}{T_{07}}, \text{ ha/sch} \quad (7)$$

where:

T_{07} – total time of the working shift, in min.

Turning coefficient (K_{21}) was determined by the equation:

$$K_{21} = \frac{T_1}{T_1 + T_{21}} \quad (8)$$

Technological safety coefficient (K_{41}) was calculated with the equation:

$$K_{41} = \frac{T_1}{T_1 + T_{41}} \quad (9)$$

Use of time coefficient of the working shift was calculated by the equation:

$$K_{07} = \frac{T_1}{T_{07}} \quad (10)$$

where:

T_{21} is the time during which the unloaded aggregate is moving at the ends of the plot, executing the return;

T_{41} - time to remove technological deficiencies.

Table 6 presents the average values of operational indices which were determined after establishing of the settings and working in optimum conditions with the windrower in aggregate with the U650M tractor.

Table 6 Operational indices determined under field conditions with the windrower powered by a 47.8 kW tractor

Parameter	Measure Unit	Results for two working speed:	
		Working speeds: 3.8 km/h	Working speeds: 6.2 km/h
Green mass yield	t/ ha	16.4	16.4
Effective work rate (W_{ef})	ha/ h	1.04	1.69
Shift working capacity (W_{sch})	ha/sch	0.75	1.25
Turning coefficient (K_{21})	-	0.96	0.94
Technological safety coefficient (K_{41})	-	0.99	0.99
Time use coefficient of the working shift	-	0.72	0.74
Fuel consumption	l/ha	6.2	5.4

CONCLUSIONS

Following the experimental research with the trailed windrower with oscillating mowing technology, sickle bar mower and rollers with two metal crushing rollers with helically bars, revealed the following conclusions:

In terms of operations, qualitative indices performed by trailed windrower are in accordance with the agro-technical requirements of the harvesting work and forage conditioning. This is proven by insignificant material losses, with low values of approx. 0.92%, and the degree of plant crushing meets the agro-technical requirements, being about 85%.

- The trailed windrower realized a satisfactory energy consumption and work rate in aggregate with U650M tractor.
- The results of present research can be used by farmers to improve forage production, especially in harvesting and conditioning technology.

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TRENDOWI RAZVOJA PREŠA ZA VALJKASTE BALE

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SAŽETAK

Porast potražnje za slamom u stočarstvu i u proizvodnji energije potiče razvoj preša za bale i uvođenje inovacija u svrhu povećanja radnog učinka. Tendencija je povećanja zbijenosti i dimenzija bale radi postizanja veće mase po bali. Manji broj bala po jedinici površine umanjuje troškove transporta i potrebna je manja količina konopa i/ili mreže za vezanje bale, te plastične folije kod spremanja travne silaže ili sjenaže. Povećava se radni zahvat sakupljačkog uređaja (Pick-up) koji već doseže širinu od 230 cm. Kod tlačnih komora sa stalnim volumenom kombiniraju se valjci zajedno s lancima s poprečnim letvama radi boljeg oblikovanja bale i veće zbijenosti. Preše s integriranim sustavom za ovijanje bala postižu veći radni učinak. U jednom proходу se jednim strojem istovremeno obavlja prešanje, ovijanje i polaganje bale bez zaustavljanja. Prema navodima proizvođača moguća je ušteda radnog vremena i do 50%. Zbog velike težine pojedinih modela preša nude se široki pneumatici radi manjeg zbijanja tla. Za elektronički sustav nadzora i upravljanja prešama iz kabine traktora sve više se primjenjuje ISO BUS tehnologija.

Ključne riječi: preša za valjkaste bale, tlačna komora preše, kombinacija preše i ovijača bala, preša sa integriranim ovijačem

UVOD

U razvijenim zemljama rašireno je korištenje preša za velike valjkaste bale za spremanje sijena, sjenaže i slame. Razvijaju se različite koncepcije rada tlačnih komora, te konstrukcije preša ili kombinacije s ovijačima koje uz prešanje omogućuju i istovremeno ovijanje bala u foliju u jednom proходу. Prednosti ovijanja bala sjenaže u plastičnu foliju u odnosu na klasičan način spremanja sjenaže u silos su izostavljanje visokih troškova podizanja silosa (Shinners et al., 2009), zatim ovijene bale se mogu ostaviti na polju i prema potrebi dopremiti na poljoprivredno gospodarstvo, ili pojedinačno prodavati. Bala ovijena plastičnom folijom predstavlja zasebni silos u kojem se odvijaju procesi siliranja. Kvalitetna travna silaža sadrži od 30% do 40% suhe tvari (Niemöller, 2007), a sijeno se

mora osušiti na 15% do 23% sadržaja vode (Srivastava et al., 2006). Prilikom baliranja travne silaže ili sjenaže bitno je postići što veći stupanj zbijenosti bale, između ostalog da bi se osigurali anaerobni uvjeti za procese siliranja u balama ovijenim folijom. Tendencija je postizanja visokog stupnja zbijenosti bala radi povećanja krmne mase po bali (Kemper, 2013) kao i povećanje dimenzije bale (Niemöller, 2009). Veći stupanj zbijenosti bale omogućuje manji broj bala po jedinici površine, a što smanjuje troškove transporta i količinu konopa i/ili mreže za vezanje bale, kao i plastične folije kod spremanja travne silaže ili sjenaže. Povećano korištenje slame za proizvodnju energije utječe na prodaju preša. Potencijalno proširenje korištenja slame kao energenta utjecat će na razvoj preša velikog učinka. Cijena slame i krme može utjecati na povećanu potražnju za prešama. Tako je u Njemačkoj zadnjih godina zabilježen trend vraćanja poljoprivrednika korištenju vlastitih, najčešće manjih preša za valjkaste bale da bi bili manje zavisni o profesionalnim davateljima usluga mehanizacije (Kattenstroth, 2012). Da bi se postupak spremanja sjenaže obavio na zadovoljavajući način, potrebno je raspolagati strojevima koji imaju visoki učinak kako bi se radovi obavili u što kraćem agrotehničkom roku (Štorman et al., 1994).

Podjela preša prema tipu tlačne komore

Osnovna podjela preša za valjkaste bale je na preše sa stalnim volumenom tlačne komore i na preše s promjenjivim volumenom tlačne komore, postoje i preše čiji je princip rada kombinacija promjenjivog i stalnog volumena tlačne komore, tzv. hibridne preše (sl. 1). Hibridne preše u početnoj fazi oblikovanja bale rade sa stalnim volumenom tlačne komore do promjera bale od 125 cm ili manjim, a nakon toga s promjenjivim volumenom tlačne komore. Konačni promjer bale se može određivati unutar opsega rada s promjenjivim volumenom tlačne komore. Najpoznatiji proizvođač preša sa stalnim i promjenjivim volumenom tlačne komore je tvrtka Krone, model Comprima F 155 ima mogućnost podešavanja konačnog promjera bale iz kabine traktora u rasponu od 125 do 150 cm.



Sl. 1 Preša sa stalnim i promjenjivim volumenom tlačne komore, Krone Comprima F 155
Fig. 1 Semi – variable fixed chamber baler, Krone Comprima F 155

U tlačnoj komori se za oblikovanje i prešanje bale koriste valjci ili lanci beskonačnog niza s čeličnim poprečnim letvama (šipkama) ili njihova kombinacija. Promjer bala oblikovanih prešama sa stalnim volumenom tlačne komore ovisno o modelu može biti u rasponu od 117 do 155 cm, a širina je od 117 do 123 cm. Tvrtka Claas razvila je Maximum Pressure System sustave koji omogućuje dodatno zbijanje bale preko tri čelična valjka smještena na gornjem dijelu tlačne komore (sl. 2). Tlačnu komoru sačinjavaju 16 čeličnih

valjaka od čega su 3 u segmentu i mogu se pomicati prema unutrašnjosti ili rubu komore. Kako se komora ispunjava biljnom masom pritišću je tri spuštene valjka i postepeno se podižu prema rubu komore gdje je smješteno preostalih 13 valjaka. MPS sustav omogućuje visoki stupanj zbijenosti jezgre i cijele bale. Prema navodu proizvođača sustav MPS Plus preko hidraulike postiže veći stupanj zbijenosti bale i za pogon mu je potrebna manja snaga traktora u usporedbi s prethodnim MPS sustavima. Pritisak prešanja je podesiv od 60 do 120 bara. Konceptcija tlačne komore sa stalnim volumenom s lancima i letvama se potvrdila u baliranju travne silaže, sijena i slame (sl. 3). Prilikom prešanja sijena i slame s većim sadržajem suhe tvari može doći do usitnjavanja biljne mase pogotovo u sušnim razdobljima, a kod prešanja travne silaže u kišnim razdobljima biljna masa može sadržavati visoki udio vode i imati veću masu. Lanci s letvama zahvaćaju krmu i oblikuju balu velike gustoće. Tlačna komora preše je izvana oklopljena (zatvorena), te su manji gubici krme. Prema navodima pojedinih proizvođača preša (Pöttinger i drugi) iskustva pokazuju da su kod preša sa valjcima na stražnjem dijelu veći gubici biljne mase. Radi smanjenja navedenih gubitaka potrebno je potpuno zatvoriti (oklopiti) stražnji dio preše kao što to imaju sustavi s lancima s letvama. Kod izvedbe s valjcima se između valjaka nakuplja biljna masa i što su valjci veći potrebna je veća snaga za njihov pogon.



Sl. 2 Claas – MPS sustav s tri valjka u segmentu na stražnjoj strani tlačne komore, za dodatni pritisak pri oblikovanju bale

Fig. 2 Claas – Maximum pressure system MPS, the swivel-mounted three-roller segment in the baler tailgate provides the additional pressure



Sl. 3 Tlačna komora stalnog volumenom s lancima i letvama (lijevo), koncept zatvorene komore (desno), Krone

Fig. 3 The bale chamber designed with chain and slat (left), concept of an enclosed bale chamber (right), Krone

Tlačna komora stalnog volumena može biti kombinacija valjaka i lanaca s letvama (sl. 4). Kod modela Vicon RF 3225 s prednje strane je šest valjaka, a preostali dio komore je sustav s lancem i letvama koji osigurava zbijenu jezgru bale i kod prosušene krme, sijena. Prednji valjci imaju funkciju završnog oblikovanja bale i postizanja visokog stupnja zbijenosti, dok sustav s lancima i letvama omogućuje zbijeniju jezgru bale. Takva kombinacija uspješno oblikuje bale velike gustoće sa suhom ili vlažnom biljnom masom. Kombiniranim sustavom stvaranja-formiranja bale može se postići veća zbijenost bale za 15 do 20%, a samim time i njena veća masa za standardnu dimenziju bale.



Sl. 4 Tlačna komora stalnog volumena s valjcima s prednje strane te lancima s poprečnim letvama na stražnjoj strani, Vicon RF 3225 (lijevo), bala slame omotana s plastičnom folijom za skladištenje na otvorenom, New Holland Roll-Bar™ (desno)

Fig. 4 The bale chamber designed with six (6) rollers at the front and chain and slat at the rear part, Vicon RF 3225 (left), for outside storage of straw bales New Holland Roll-Bar™ balers can work with full width plastic film

Povećala se zastupljenost preša za valjkaste bale s promjenjivim volumenom tlačne komore u odnosu na preše za valjkaste bale sa stalnim volumenom tlačne komore. (Wiedermann, 2010). Promjer bala oblikovanih prešama s promjenjivim volumenom tlačne komore ovisno o modelu može biti u rasponu od 60 do 200 cm, a širina od 120 do 123 cm (tablica 1).

Kod preše za valjkaste bale s promjenjivim volumenom tlačne komore cilj je bio postići brzinu prešanja od $3,0 \text{ m s}^{-1}$ u svrhu postizanja većeg učinka (Niemöller, 2008). Preša Variant, proizvođača Claas ima brzinu beskonačnih traka od $3,0 \text{ m s}^{-1}$, što omogućuje brže oblikovanje bale i veću zbijenost. Zbijenija jezgra bale je poželjna kod prešanja slame, dok je za sijeno prikladnija manje zbijena jezgra koja se može prozračivati, a bale travne silaže ili sjenaže s manje zbijenom jezgrom lakše je otvarati prilikom hranjenja. Modeli RP 545 - tvrtke Lely Welger, 520 V - tvrtke Massey Ferguson i RV 4220 - tvrtke Vicon mogu oblikovati balu promjera do 2,00 m, te širine 1,20 i 1,23 m, volumena blizu 4 m^3 . Tvrtka John Deere je s ciljem većeg učinka razvila sustav brzog istovara bale $< 5 \text{ s}$ (sl. 5) (Kattenstroth, 2012). Tvrtka Krone za svoje modele Comprima primjenjuje NovoGrip koncept kod sva tri načina oblikovanja bale u tlačnoj komori. Biljnu masu zahvaćaju i pritišću poprečne letve (cijevi) povezane i pogonjene s dvije beskonačne trake velike čvrstoće, napravljene od gume i slojeva tkanine od poliestera i poliamida.

Bale se mogu vezati špagom ili mrežom, a kod nekih modela moguća je i kombinacija mreže i špage. Radi zaštite bale od slame prilikom skladištenja na otvorenom tvrtka New Holland za Roll-Bar™ modele ima mogućnost omatanja plašta bale s plastičnom folijom u

tlačnoj komori. Proizvođač navodi da i kod spremanja sjenaže odnosno travne silaže dodatni slojevi plastične folije prije ovijanja bale ovijačem mogu pospješiti procese siliranja. Za elektronički sustav nadzora i upravljanja prešama iz kabine traktora sve više se primjenjuju ISO BUS standard (Kemper, 2013). U radu s traktorom kompatibilnim s ISO 11783 standardom dodatna upravljačka kutija za prešu nije potrebna. Široki pneumatici se nude kao opcija kod modela velike težine koja može iznositi i do 4 t, a kod kombinacije preše i ovijača i preko 6 t, čak i 11,4 t (tablica 1 i 2).



Sl. 5 Preša s promjenjivim volumenom tlačne komore, John Deere serija 900
Fig. 5 Variable chamber baler, John Deere series 900

Sakupljački uređaj (Pick-up) i sustav za rezanje krme

Trend je u povećanju radnog zahvata (Pick – up) sakupljačkog uređaja radi postizanja većeg učinka, dosegnut je širina od 230 cm s mogućnošću korištenja noževa (Kemper, 2013). Veliki radni zahvati su preko 200 cm, i modeli preša koji imaju radni zahvat preko 210 cm prema DIN-u 11220 su prikazani u tablicama 1 i 2. Veći broj opružnih zubaca uz visoku brzinu okretanja omogućuje učinkovito podizanje i biljne mase manje duljine. Sakupljački uređaj (Pick-up) poboljšavan je za bolje „kopiranje“ mikro reljefa pri velikim radnim brzinama i okretanju na uvratini. Navedeno pridonosi očuvanju travnjaka i smanjenom onečišćenju krme zemljom. Brži i ravnomjerniji protok biljne mase od pick-up uređaja do tlačne komore omogućuje potisni rotor. U slučaju zagušenja krmom u radu odnosno zastoja rotora moguće je uključiti suprotan smjer vrtnje radi deblokiranja, ovisno o modelu ručno ili preko hidrauličkog sustava iz kabine traktora.

Usitnjena biljna masa može biti više zbijena, što omogućuje manji broj bala. Otvaranje bale, priprema i raspodjela stočne hrane je lakša i brža sa isjeckanom krmom, i bolje apsorbira životinjske izlučevine. Pojedini modeli preša imaju noževe smještene između sakupljačkog pick-up uređaja i tlačne komore. Najmanja teoretska duljina sječke može iznositi 40 mm (Massey Ferguson 225F Super – Cut s 25 noževa), 42 mm (Krone Comprima F 125 XC s 26 noževa) ili biti veća. Ukupan broj noževa može biti od 14 do 26 komada, uključivati se mogu svi ili po segmentima-skupinama, a mogu se i potpuno isključiti. Tijekom dana možemo periodički izmjenjivati skupine noževa, čime se usporava trošenje oštrica, a i manji je utrošak goriva u odnosu na uključivanje svih noževa. Mehanizmi za skupljanje krme s tla i unošenje u tlačnu komoru su zaštićeni od preopterećenje kliznom spojkom na zglobnom vratilu (kardanu) koja se automatski uključuje. Dodatna zaštita je spuštanje dna dovodnog kanala što omogućuje konstantan protok krmne mase u

tlačnu komoru (sl. 6). Kada nastupi zagušenje dno dovodnog kanala se spušta preko hidrauličkog sustava upravljivog iz kabine traktora, zatim rotor kroz sada prošireni dovodni kanal nesmetano potiskuje krmnu masu direktno u tlačnu komoru. Kod sustava s noževima za usitnjavanje krme spuštaju se i noževi omogućujući veći razmak/presjek za prolaz biljne mase. Nakon što je otklonjena mogućnost zagušenja dno dovodnog kanala s noževima se podiže. U ekstremnim situacijama postoji dodatna zaštita sa zasebnom spojkom za pogon potisnog rotora, te iako se potisni rotor ručno ili hidraulički isključi bala se može do kraja oblikovati u tlačnoj komori (tvrtka Deutz Fahr). Sustav spuštanja dna dovodnog kanala oznake Pro tvrtke Claas je “prilagodljiv” uvjetima rada tako što omogućuje automatsko spuštanje dna do 30 mm, te omogućuje kontinuirani protok i kvalitetno sjeckanje krmne mase.



Sl. 6 Spuštanje dna dovodnog kanala hidraulikom, Claas
Fig. 6 Hydraulically lowerable floor, Claas

Preše s integriranim sustavom za ovijanje bala – kombinacija preše i ovijača

Možemo ih podijeliti na kombinaciju preše i ovijača gdje je ovijanje bale na donjem dijelu tlačne komore ili izvan tlačne komore. Kod prvog načina bala nakon oblikovanja ostaje u tlačnoj komori i podiže se gornji dio preše, te započinje postupak ovijanja u trajanju od 18 s. Takvim postupkom bala zadržava svoj oblik što umanjuje mogućnost ulaska zraka tijekom postupka ovijanja. Naime, kod uobičajenog postupka ovijanja izvan tlačne komore prilikom prebacivanja bale na tlo ili na ovijač može doći do povećanja njenog volumena zbog deformacije oblika, a time i do ulaska zraka u balu. Tlačna komora je stalnog volumena s osamnaest valjaka, sakupljački pick-up uređaj je širok 230 cm i može imati do 23 noža za usitnjavanje krme. Prvi model je bio Taarup BIO, Kverneland - Taarup (sl. 7), a današnji modeli su Compacmaster, Deutz Fahr i i-BIO, Kuhn. Preša s ovijanjem na donjem dijelu tlačne komore je pogotovo pogodna za rad na manjim površinama, vlažnijim terenima i na nagibima. S kombinacijom prešanja i ovijanja bale izvan tlačne komore postiže se veći radni učinak, u jednom proходу s jednim strojem se istovremeno obavlja prešanje i ovijanje, a zatim polaganje bale bez zaustavljanja. Dok se u tlačnoj komori oblikuje nova bala istovremeno se druga bala ovija. Za modele Rollant Claas Uniwrap, prebacivanje bale iz tlačne komore na ovijač traje 17 s, a zavisno od slojeva plastične folije ovijanje bale traje 23 s za 6 slojeva, te 17 s za 4 sloja. Navodi se da je za 200 bala sjenaze konvencionalnim postupkom potrebno 5 h za prešanje i 5 h za ovijanje plastičnom folijom, dok je za model Uniwrap s istovremenim prešanjem i ovijanjem potrebno između 5 i 6 h. Prema navodima tvrtke Krone s modelom Ultima CF 155 XC oblikuje se i ovije plastičnom folijom 50% više bala u odnosu na zasebnu primjenu preše i ovijača.

Tablica 1 Preše za valjkaste bale različitih izvedbi tlačne komore
Table 1 Round balers with different types of bale chamber

Proizvođač i model:	Dimenzije tlačne komore - bale:		Snaga za pogon	Pick-up:		Težina
	Promjer	Širina		DIN*	Širina	
<i>Mjerna jedinica</i>	m		kW	m		kg
Claas						
Rollant 455 RC PRO	1,25-1,35	1,20	--	1,90	2,10	3.300
Deutz Fahr						
Fix-master FM 235 Opticut 23	1,25	1,22	--	--	2,30	3.295
John Deere						
F440DR	1,25-1,35	1,17	75	1,86	2,00/2,20	--
990	0,80-1,85	1,21	75	2,12	2,20	2.845
Krone						
Comprima F125 XC X-treme	1,25-1,30	1,20	48	2,15	--	--
Comprima F155 XC X-treme	1,25-1,50	1,20	51	2,15	--	--
Comprima V150 XC X-treme	1,00-1,50	1,20	51	2,15	--	--
Kuhn						
FB 2135 Opticut 23	1,25	1,22	--	--	2,30	3.295
VB 2190 OPTICUT	0,80-1,85	1,20	60	--	2,30	2.950
Lely Welger						
RP 245 Profi	1,25	1,23	80	--	2,25	--
RP 545	1,00-2,00	1,23	81	--	2,25	3.920
Massey Ferguson						
520V SC25	0,60-2,00	1,20	74	--	2,20	3.920
McHale						
F5600	1,25	1,23	75	--	2,00	3.700
V660	0,60-1,68	1,23	60	--	2,00	4.000
New Holland						
Roll Baler 125	1,25	1,20	--	--	2,10	2.800
Roll Belt 180	0,90-1,80	1,20	75	--	2,20/2,30	3.815
Pöttinger						
3150 L	1,55	1,20	44	--	2,00	2.290
3300 L SC	1,25	1,20	66	--	2,00	3.350
Vicon						
RV 4220 SC25	0,60-2,00	1,20	74	--	2,20	3.920

-- vrijednosti nisu navedene, * DIN 11220

Preše sa stalnim volumenom tlačne komore
Preše s promjenjivim volumenom tlačne komore
Preše sa stalnim i promjenjivim volumenom tlačne komore

Tablica 2 Kombinacije preša i ovijača različitih izvedbi tlačne komore
Table 2 Round baler combinations with different types of bale chamber

Proizvođač i model:	Dimenzije tlačne komore - bale:		Snaga za pogon	Pick-up:		Težina
	Promjer	Širina		DIN	Širina	
<i>Mjerna jedinica</i>	m		kW		m	kg
Claas						
Rollant 455 RC UNIWRAP	1,25-1,35	1,20	--	1,90	2,10	5.500
Deutz Fahr						
Compacmaster OPTICUT 23	1,25	1,22	90	--	2,30	3.936
John Deere						
C440R	1,25-1,35	1,17	82	1,86	2,00	--
Krone						
Comprima CV 210 XC	1,00-2,05	1,20	81	2,15	--	--
Ultima CF 155 XC	1,25-1,50	1,20	105	2,15	--	11.400
Kuhn						
i-BIO OPTICUT 14	1,25	1,22	80	--	2,30	3.495
Lely Welger						
RPC 445 Tornado	0,90-1,60	1,23	97	--	2,25	6.100
McHale						
Fusion 6	0,60-1,68	1,23	85	--	2,00	6.500
New Holland						
Roll Baler 135 Ultra	1,35	1,20	--	--	2,20	4.900
Vicon						
RV 4220 SC25 FlexiWrap	0,60-2,00	1,20	74	--	2,20	6.720

-- vrijednosti nisu navedene, * DIN 11220

Preše sa stalnim volumenom tlačne komore s ovijanjem bale izvan tlačne komore

Preše s promjenjivim volumenom tlačne komore s ovijanjem bale izvan tlačne komore

Preše sa stalnim i promjenjivim vol. tlačne komore s ovijanjem bale izvan tlačne komore

Preše sa stalnim volumenom tlačne komore i ovijanjem bale u donjem dijelu tlačne komore

Prilikom prešanja slame ili sijena bala se iz tlačne komore prebacaju na ovijač koji zatim balu odmah istovaruje na tlo bez zaustavljanja stroja. Radi sigurnijeg prebacivanja bale iz tlačne komore na ovijač pri radu na nagibima tvrtka McHale je na modelima Fusion ovijač bala ogradila bočnim stranicama (sl. 7). Kombinacija preše i ovijača bala izvan tlačne komore ovisno o modelu može biti sa stalnim ili promjenjivim ili stalnim-promjenjivim volumenom tlačne komore.



Sl. 7 Preša s integriranim sustavom za ovijanje bale, Taarup BIO, Kverneland (lijevo), kombinacija preše i ovijača ograđenog bočnim stranicama tlačne komore, McHale Fusion (desno)

Fig. 7 Baler with integrated wrapper, taarup BIO, Kverneland (left), round baler wrapper combination with the sidewalls of the chamber for wrapping table, McHale Fusion (right)

ZAKLJUČAK

U cilju postizanja kvalitetnije sjenaže i povećanja radnog učinka u baliranju teži se većoj zbijenosti bale, a što omogućuje kvalitetnije siliranje i manji broj bala po jedinici površine. Manji broj bala omogućuje smanjenje troškova transporta i manji utrošak konopa ili mreže, kao i uštedu plastične folije za ovijanje.

Radi boljeg oblikovanja bale u tlačnoj komori sa stalnim volumenom unapređuje se koncepcija s valjcima primjenom zasebna tri valjka u segmentu za dodatni pritisak na biljnu masu. Kombinacija valjaka i lanaca s letvama uspješno oblikuje bale velike gustoće sa suhom ili vlažnom biljnom masom. NovoGrip koncepcija tvrtke Krone u modelima Comprima u tlačnoj komori uz poprečne letve umjesto lanaca koristi beskonačne trake velike čvrstoće, napravljene od gume i slojeva tkanine od poliestera i poliamida. Skraćeno je vrijeme potrebno za istovar bale iz tlačne komore na 5 s kod preša tvrtke John Deere serije 900. Sakupljački pick-up uređaj je dosegao širinu od 230 cm, a kao dodatna zaštita od zagušenja i zastoja u radu između sakupljačkog pick-up uređaja i tlačne komore je mogućnost spuštanja dna dovodnog kanala za konstantan protok krmne mase.

Kombinacija preše i ovijača kao jednog stroja omogućuje velike radne učinke pošto se u jednom proходу bez zastoja istovremeno obavlja baliranje, ovijanje i istovar bala.

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RECENT DEVELOPMENT OF ROUND BALERS

SUMMARY

The increase in demand for straw used in livestock and energy production, will drive the further increase of the balers efficiency. The compaction performance will be improved to increase crop mass per bale. The reduced

amount of bales per hectare reduces transport costs and additional expenses such as binding material (net/twine) and wrapping film for bale ensilage. The Pick-up gathers the crop material over a width of 230 cm. The fixed chamber baler designed with rollers and endless chain conveyor (chain and slat elevator concept) gives high density and well-shaped bales. Balers with an integrated system for wrapping, baler-wrapper combinations, are achieving higher efficiency. In one pass the one machine simultaneously bales, wraps and unloads the bale on the move. According to the manufacturers it is possible to save work time up to 50%. Wide flotation tires are available to reduce soil compaction. Almost all manufacturers are striving to equip their models with ISOBUS technology.

Key words: round baler, bale chamber, round baler wrapper combination, baler with integrated wrapper



QUALITY OF MECHANICAL HARVESTING OF CHAMOMILE INFLORESCENCES

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SUMMARY

Quality requirements for harvested material are very strict when medicinal and aromatic plants. Mechanized harvesting can guarantee, for cultivated species, obtaining of profitable productions characterized by high productivity and improved quality of the product collected.

This paper summarizes investigation conducted in the INMA related to chamomile inflorescences mechanized harvesting with different sizes of active bodies, analyzing the quality of each of them and the quality of the outcome. For three dimensional versions of combs, the inflorescences harvesting degree had registered values higher 84%.

The results enable a complete work performances evaluation for chamomile inflorescences harvesting equipment, in each case studied. They can also be an important prerequisite for the development of advanced specialized equipment adapted to the conditions of Romania and other countries with similar conditions, in accordance with sustainable agriculture principles and practices.

Key words: *chamomile inflorescences, mechanized harvesting, qualitative indexes.*

INTRODUCTION

The phytotherapeutic efficiency of the medicinal and aromatic plants depends among other factors, and of the vegetal material quality, obtained following a harvesting process, differentially conducted, depending on the species, on the useful organ of the plant and on the season (Dihoru 2008).

Cultivation of medicinal and aromatic plants offers the possibility of obtaining large quantities of raw material, more homogeneous and more rich in active ingredients, as well

as the one of performing of harvesting at the optimal time, when the content of active ingredients from the plants is maximum (Verzea et al 2002, Roman et al 2009). Harvesting of medicinal and aromatic plants is the most difficult work within the culture technologies, for which are consumed approx. 30-80% of the total works (Muntean 1990, Roman et al 2009).

The chamomile (*Matricaria chamomilla* L.) is one of the most known and used medicinal plants, used since ancient times. It is grown for its flowers which contain 0.5-1.5 % volatile oil rich in azulene, flavonoids and coumarins (Muntean 1990, Costescu et al 2008). For the inflorescences of chamomile the content of volatil oil varies from one country to another (Muntean 1990). At world level, approximately 20,000 ha of field are cultivated by chamomile, the main producers being Argentina, Egypt, Italy, Hungary, Germany, Serbia etc. Large-scale production of chamomile can be achieved only through the mechanization of the harvesting process, using equipment endowed with various types of harvesters (Martinov and Konstantinovic 2007, Ivanovic et al 2014). From the constructive point of view, they may be of the drum or transporter type, but picking tools are in almost all cases some kind of comb (Martinov and Konstantinovic 2007, Brabant and Ehlert 2011).

Because of working parts type, the working process is, in fact a picking, which comprises, as all the processes of the kind, the following stages:

- a) Combs penetrating into the crop horizon;
- b) Combs displacement along the stems;
- c) Combs coming from the stem layer (Neculaiasa and Danila 1995, Brabant and Ehlert 2011).

MATERIAL AND METHODS

The experiments were carried out in a chamomile culture from the Romanian variety "Margaritar" (Verzea et al 2002), that had the following characteristics: average diameter of inflorescences 19.4 mm, the height at which existed the flowers on the plants was between 298 mm (minimum) and 583mm (maximum).



Fig.1 Chamomile harvester

For the chamomile harvesters (Figure 1) the basic subassembly is represented by the harvest device for chamomile inflorescences. It has the functional role of detaching the inflorescences of stalks and to introduce them into the machine technological flow. Machine for harvesting chamomile is trailed and works offset from the tractor, being provided with mechanical transmission. The harvester moves on the direction of the rows of plants, with the scrapers combs in action. These perform the combing of the plants from the bottom to top, having as effect the detachment of the inflorescences from stalks.

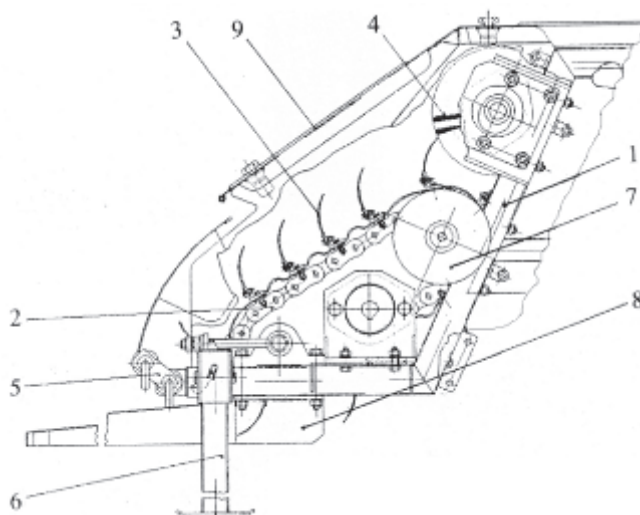


Fig. 2 Harvest device for chamomile inflorescences

In the working process, the combs perform a parallel plan movement, resulting from the overlapping of the rotary motion of the harvester band over the translational movement given by the movement of the aggregate. This ensures for each point from the plucking bodies (characterized by a position vector from the center of rotation) a cycloidal trajectory (Martinov and Konstantinovic 2007). The action of the scrapers combs includes the floral floors which is harvested depending on the established working height. Chamomile inflorescences collected during harvesting are taken over by a conveyor, to be to be spilt into the machine hopper. Its unloading is made at ground level, by swinging a mobile wall driven by hydraulic cylinder.

The working width of the equipment ($W=2000$ mm), the combs pitch on band ($p=100$ mm) and the frequency of rotation of the discharging brush ($f=400$ min⁻¹), were not changed during the experiments.

In figure 2 are shown the scheme and the main elements comprised in harvest device for chamomile inflorescences: 1- supporting frame; 2 – conveyor-type picker; 3 - raking combs; 4 – cylindrical brush; 5 – inflorescences captor system; 6 –propping support; 7 – mechanical transmission; 8 – working height limiting device; 9 – front guard.

Several types of raking combs with straight teeth (Figure 3a) and, respectively, curved teeth (Figure 3b) have been manufactured and tested. For the curved teeth is presented only the side view, in order to highlight the differences. At both teeth types the gap between teeth is rounded “U”-shaped. Gap adjusting ray is equal to half of distance between teeth ($d/2$).

This type of harvesting device (with conveyor-type picker and scrapers combs) is suitable for chamomile harvester with lower working capacity, compared to some of new advanced solutions, such as the self-propelled combines for chamomile harvesting of high productivity, in the field (Ehlert and Beier 2014).

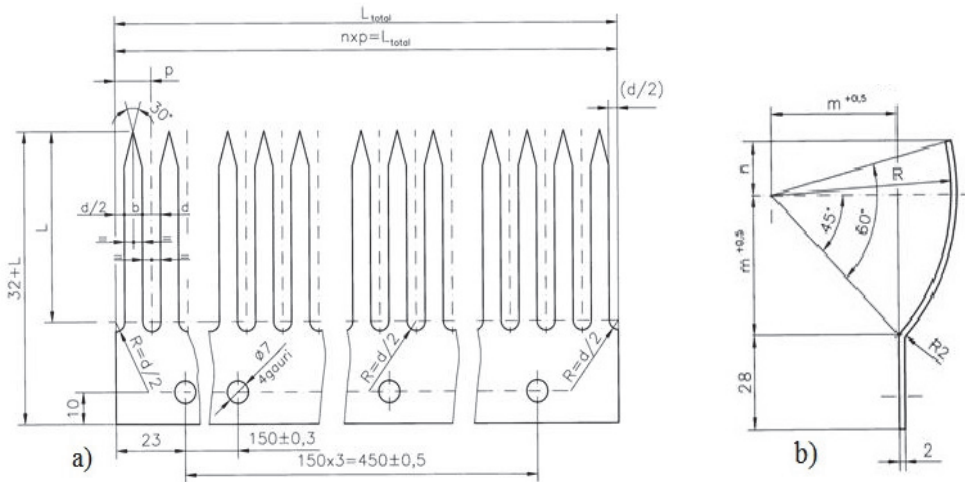


Fig. 3 The shape of combs: a) with straight teeth; b) with curved teeth

Notations used in Figure 3 and Table 1, in which are shown the dimensional characteristics of the combs, have the following meanings: d – distance between two consecutive teeth; p – teeth pitch; L – teeth length; b – teeth width; R – radius of curvature of combs with curved teeth. The dimensions m and n can be expressed and calculated according to the radius R .

The table 1 presents the 12 typo dimensions of teeth scrapers, for identifying of which were used the following symbols:

- a) combs with straight teeth - M_1 ; N_1 ; O_1 ; S_1 ; T_1 ; V_1 .
- b) combs with curved teeth - M_2 ; N_2 ; O_2 ; S_2 ; T_2 ; V_2 .

In order to be more easily compared the dimensional versions are presented pairs for the common sizes (the version with straight teeth, followed by the one with curved teeth). The first six versions have the distance between teeth $d=6\text{mm}$, the others have the distance $d=4\text{mm}$. The teeth width and length varies in the same manner for the versions grouped by distance d .

Table 1 The dimensional characteristics of the combs

Comb symbol	d [mm]	b [mm]	p [mm]	L [mm]	R [mm]	$m = \frac{\sqrt{2}}{2} R$ [mm]	n [mm]
M1	6	6	12	60	-	-	-
M2	6	6	12	60	60	42	16
N1	6	8	14	80	-	-	-
N2	6	8	14	80	80	57	21
O1	6	10	16	100	-	-	-
O2	6	10	16	100	100	71	26
S1	4	6	10	60	-	-	-
S2	4	6	10	60	60	42	16
T1	4	8	12	80	-	-	-
T2	4	8	12	80	80	57	21
V1	4	10	14	100	-	-	-
V2	4	10	14	100	100	71	26

By the use of interchangeable chain wheels, with different numbers of teeth ($Z=12; 21; 29$) was obtained the gear ratio modification of the movement to harvester and implicitly the obtaining of different linear speeds ($v_b = 0.52; 0.76; 1.08 \text{ ms}^{-1}$) of the band, on which were mounted in series the 12 variants of active organs (scrapers combs).

The experiments have been conducted varying the working speed, for each of the active parts types and sizes, for each linear speed of the band (v_b) in the case of harvesting at a working height $H = 0.300\text{m}$ as well as in the case of a working height of $H=0.450\text{m}$.

The chamomile flowers are harvested in sunny days, after it has been raised the dew, when 50% of tubular flowers from the capitulum are opened, and the ligulated flowers are in horizontal position and have a fresh look. In other words, the optimal harvesting moment is situated in the phase in which the ratio between the floral buttons and the flowered capitulas is 1: 1. (Muntean 1990, Roman et al 2009).

Harvesting is a key point in the production chain as it has a major impact on quantity and quality (Beier and Ehlert 2014). For evaluating the process quality, it was first envisaged to perform an as complete as possible harvest, expressed by the inflorescences harvesting degree. Then, the value of the product harvested was evaluated using the specific qualitative indexes.

RESULTS

The inflorescences harvesting degree, is expressed in percentages and is defined as being the ratio between the number or quantity of flowers detached (from stems) and collected during harvesting, and number or quantity of flowers existing on plants before harvesting.

In Figure 4 is shown the variation of the degree of harvesting for each type and size, for different working speeds ($v=0.5$; 0.76 ; 1.04 ; 1.22 km/h), corresponding to a linear speed of the band $v_b = 0.52$ ms⁻¹, which remains constant for every case.

The values obtained for different working heights ($H=0.300$ m and $H=0.450$ m) are presented in parallel, in order to be compared more easily.

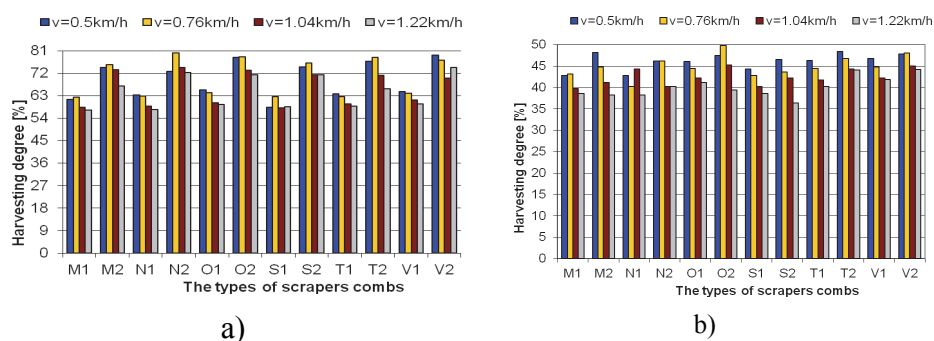


Fig. 4 Harvesting degree for $v_b = 0.52$ ms⁻¹ and the harvesting height a) $H = 0.300$ m and b) $H=0.450$ m (working speed $v=0.5$; 0.76 ; 1.04 ; 1.22 km/h)

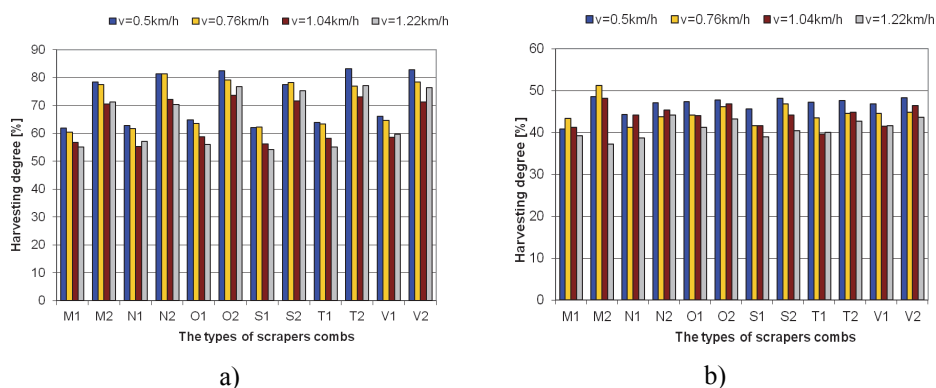


Fig. 5 Harvesting degree for $v_b = 0.76$ ms⁻¹ and the harvesting height a) $H = 0.300$ m and b) $H=0.450$ m (working speed $v=0.5$; 0.76 ; 1.04 ; 1.22 km/h)

Figure 5 shows the variation of the degree of harvesting for a linear speed of the band $v_b = 0.76$ ms⁻¹, depending on the same elements as in the previous figure.

The important active ingredients of chamomile are contained mostly into flowers, whose capitalization is done depending on the their quality. The most precious and valuable in active substances is "the high quality". This is represented only by complete inflorescences, without peduncle or with the peduncle length < 10 mm.

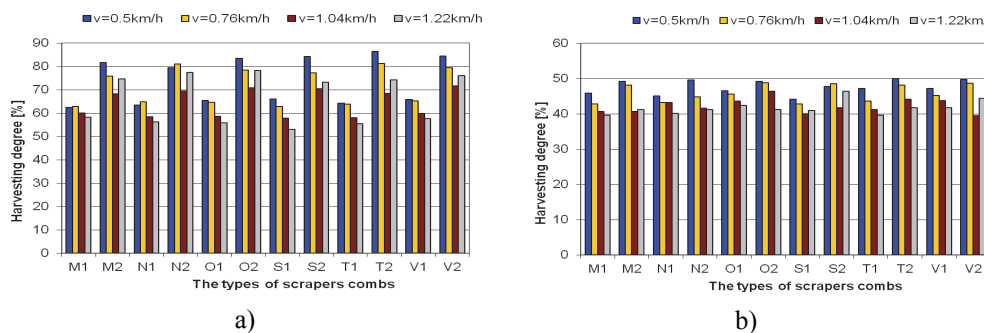


Fig. 6 Harvesting degree for $v_b = 1.08 \text{ ms}^{-1}$ and the harvesting height a) $H = 0.300 \text{ m}$ and b) $H = 0.450 \text{ m}$ (working speed $v = 0.5; 0.76; 1.04; 1.22 \text{ km/h}$)

We have defined the high quality ("high-Q") inflorescences content as the ratio between the number or amount of high quality chamomile inflorescences (defined above) and the total number, respectively the total quantity of the sample of inflorescences to be analyzed.

Figure 7 shows the variation of "high-Q" inflorescences content for each type and size, for different working speeds ($v = 0.5; 0.76; 1.04; 1.22 \text{ km/h}$), corresponding to a linear speed of the band $v_b = 0.52 \text{ ms}^{-1}$ which remains constant for every case. Also, the values obtained for different working heights ($H = 0.300 \text{ m}$ and $H = 0.450 \text{ m}$) are presented in parallel, in order to be compared more easily.

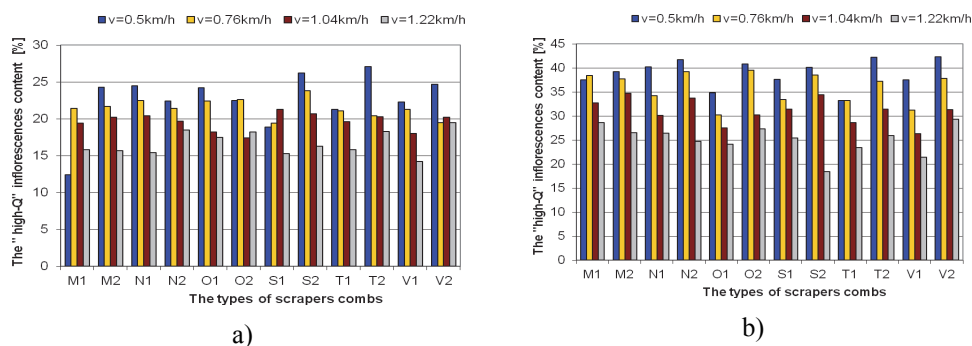


Fig. 7 The "high-Q" inflorescences content for $v_b = 0.52 \text{ ms}^{-1}$ and the harvesting height: a) $H = 0.300 \text{ m}$ and b) $H = 0.450 \text{ m}$ (working speed $v = 0.5; 0.76; 1.04; 1.22 \text{ km/h}$)

Figure 8 shows the variation of the "high-Q" inflorescences content for a linear speed of the band $v_b = 0.76 \text{ ms}^{-1}$, depending on the same elements as in the previous figure.

Figure 9 shows the variation of the "high-Q" inflorescences content for a linear speed of the band $v_b = 1.08 \text{ ms}^{-1}$, in the same conditions as in Figures 7 and 8.

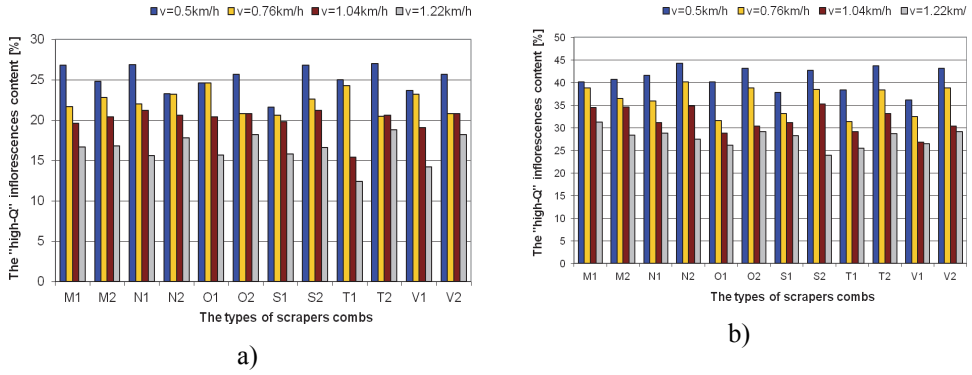


Fig. 8 The "high-Q" inflorescences content for $v_b = 0.76 \text{ ms}^{-1}$ and the harvesting height: a) $H = 0.300 \text{ m}$ and b) $H = 0.450 \text{ m}$ (working speed $v = 0.5; 0.76; 1.04; 1.22 \text{ km/h}$)

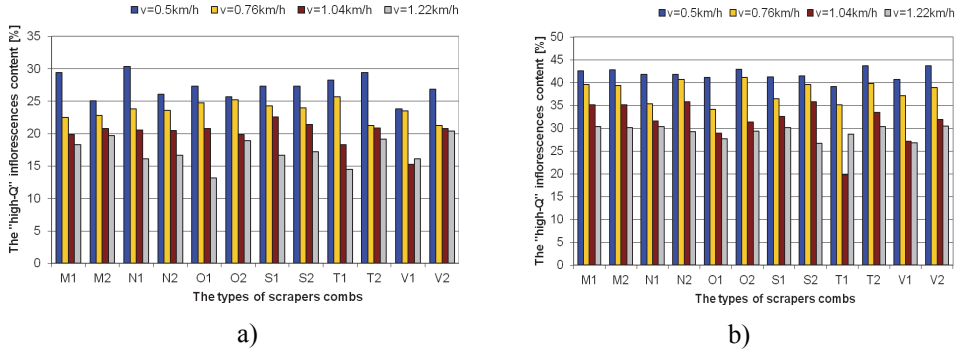


Fig. 9 The "high-Q" inflorescences content for $v_b = 1.08 \text{ ms}^{-1}$ and the harvesting height: a) $H = 0.300 \text{ m}$ and b) $H = 0.450 \text{ m}$ (working speed $v = 0.5; 0.76; 1.04; 1.22 \text{ km/h}$)

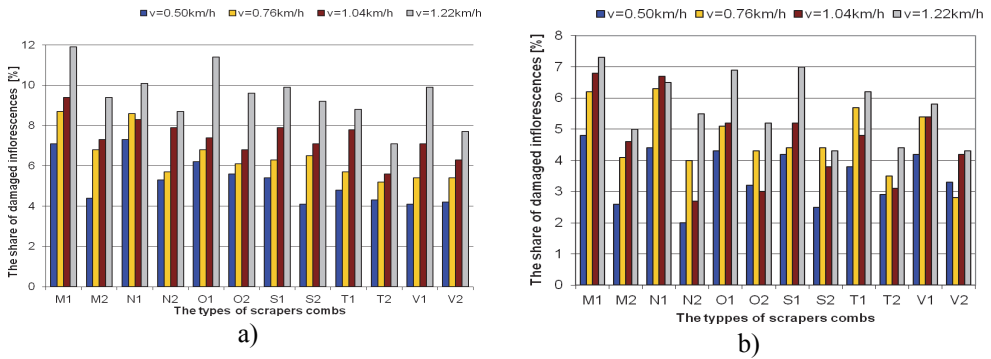


Fig. 10 The share of damaged inflorescences for $v_b = 0.52 \text{ ms}^{-1}$ and the harvesting height: a) $H = 0.300 \text{ m}$ and b) $H = 0.450 \text{ m}$ (working speed $v = 0.5; 0.76; 1.04; 1.22 \text{ km/h}$)

Besides the high quality inflorescences content, the harvested material can be characterized and by: the share of damaged inflorescences, the purity of the harvested product as well as the losses of inflorescences on the ground. Of these we considered most relevant the share of damaged inflorescences harvested, because from these is extracted the valuable volatile oil, in blue color.

Figure 10 shows variation of the share of damaged inflorescences harvested for each type and size, for different working speeds ($v=0.5$; 0.76 ; 1.04 ; 1.22 km/h), corresponding to a linear speed of the band $v_b = 0.52 \text{ ms}^{-1}$ which remains constant for every case. In this case also, the values obtained for different working heights are presented in parallel to be compared more easily.

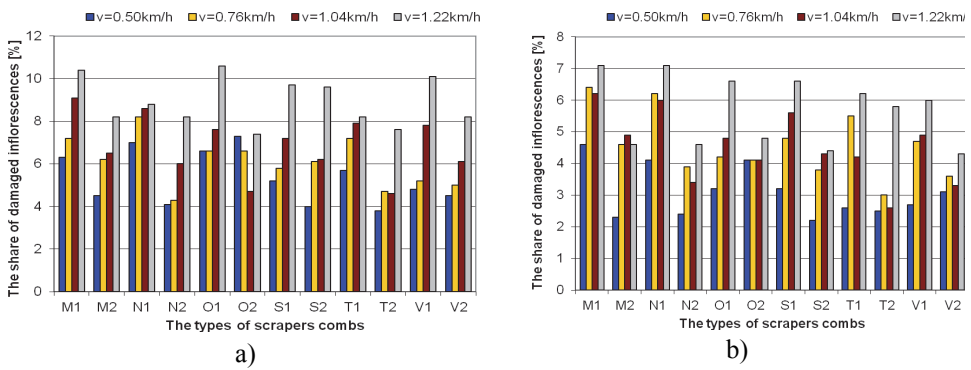


Fig. 11 The share of damaged inflorescences for $v_b = 0.76 \text{ ms}^{-1}$ and the harvesting height a) $H = 0.300$ m si b) $H=0.450$ m (working speed $v=0.5$; 0.76 ; 1.04 ; 1.22 km/h)

Figure 11 shows the variation of the share of damaged inflorescences harvested, for a linear speed of the band $v_b = 0.76 \text{ ms}^{-1}$, depending on the same elements as in the previous figure.

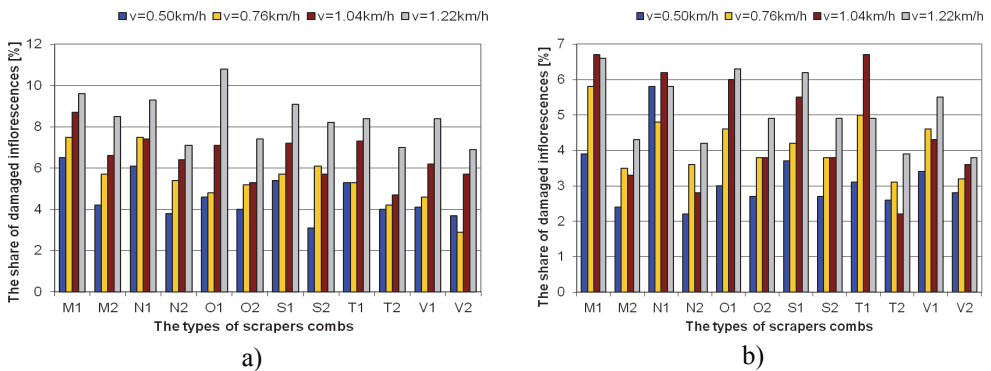


Fig. 12 The share of damaged inflorescences for $v_b = 1.08 \text{ ms}^{-1}$ and the harvesting height a) $H = 0.300$ m si b) $H=0.450$ m (working speed $v=0.5$; 0.76 ; 1.04 ; 1.22 km/h)

Figure 12 shows the variation of the share of damaged inflorescences harvested, for a linear speed of the band $v_b = 1.08 \text{ ms}^{-1}$, in the same conditions as in Figures 10 and 11.

CONCLUSIONS

Analysis of experimental research results shown in figures 4, 5, 6 emphasizes the following aspects:

- harvesting degree of active parts of comb with curved teeth -type is superior to that of straight teeth combs, by approx.14%;
- harvesting degree has decreasing values along to working speed increase, for the same type of active parts and similar operating regime, the variation domain framing between 5...8%;
- increasing the linear speed of the harvester band and therefore the peripheral speed of the active organs (scrapers combs) favorably influences the harvesting degree of inflorescences, with values ranged between 1...10%;
- harvesting degree has higher values for "low harvesting" in comparison with "high harvesting", the differences between the two harvestings being of about 20%, in favour of the "low harvest" (picker working height $H=0.300\text{m}$);
- the most advantageous situation in terms of harvesting degree is in case of using curved teeth, variants S_2 , T_2 , V_2 . For these variants, the harvesting degree has maximum values, framing between 84.2% and 86.4%, in case of low harvesting ($H=0.300$), with minimum working speed ($v=0.5\text{km/h}$), at maximum linear speed of band ($v_b=1.08\text{m s}^{-1}$).

The high quality inflorescences content records maximum values at a low working speed ($v=0.5\text{km/h}$), in case of high harvesting ($H=0.450\text{m}$), at maximum linear speed of band ($v_b=1.08\text{m s}^{-1}$).

The share of damaged inflorescences varies inversely with the peripheral speed of active bodies, the flowers being the least affected when the linear speed of the conveyor-type picker is the maximum.

The overall analysis of the results obtained at experimentations highlight the superiority of the combs with curved teeth compared to those with straight teeth and of the "dynamic plucking" compared to the "slow plucking", the N_2 and T_2 variants being the most agreed.

The results support the performing the harvesting of chamomile inflorescences in two phases. It is recommended that at the beginning to perform a "high harvest" and across 5 ... 17 days to perform a "low harvest". In this period of time the culture regenerates and the flowers from the lower floors reach to maturity.

The results obtained are arguments in order to relaunch the camomile cultivation in Romania, as well as to achieve of some efficient equipment for the harvesting of its inflorescences. In the context of the sustainable agriculture, the mechanized harvesting represents an important prerequisite for achieving of profitable productions of medicinal and aromatic plants.

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COMPARISON OF SELF PROPELLED FORAGE HARVESTERS IN MAIZE HARVESTING

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SUMMARY

Forage harvesters should chop crop mass to particles having short and uniform lengths. Length distribution of forage particles represents an important parameter for ruminant's diet formulation, especially for dairy cattle. During silage production, harvest considerations should be focused to obtaining the adequate particle size distribution of the ensiling crop particles. This paper presents the results of mining studies of three different forage harvesters at harvesting maize for silage preparation. The aim of this testing is to determine the operational characteristics and quality of the following forage harvesters Claas Jaguar 675, Zmaj 350 and John Deere 5820. The average yield of the mass was about 26 t ha⁻¹. Based on these results, it is concluded that the losses due to cutting height range from 3.83% to 5.97%. Clear relation between working velocity of forage harvesters and losses caused by inappropriate cutting height was proved. These two parameters are directly proportional, i.e. their connection is strong ($R^2 = 0.88$) and linear. All three harvesters achieved fairly acceptable cut lengths of harvested maize particles. However, experimental results verify the operational supremacy of forage harvesters Claas Jaguar 675 and John Deere 5820 with relation to the long used forage harvester Zmaj 350. The minimum deviation achieved for long chopped mass in relation to the setting, was recorded when storing silage with silage Claas Jaguar 675 in which the average length of chopped mass was 9.97 mm, where as for the fraction of length up to 10 mm was 69.87%.

Key words: forage harvester, quality of work, losses.

INTRODUCTION

Maize silage represents a common substitute for expensive concentrated food in the cattle diets. Because of high sugar content and low protein content, maize is known as a very good plant for ensilaging (Podkowka, 2003). Numerous factors influence quality of prepared silage, including climatic conditions during the season and condition of the crop used for silage preparation (Ball et al., 2001). The aim of ensiling is to produce silage of the highest quality that satisfies numerous nutritional requirements (Dinić et al., 2005).

Nowadays, a variety of different types of silage combines exists (Petrović et al., 2012). Depending on particular circumstances, like crop yield and species, terrain conditions, etc., specific harvester system can be used: a tractor-powered machine, self-propelled combine or a self-loading forage wagon system. To make an optimal choice of applied system, relevant and reliable information is necessary (Marsh, 2011). These factors are power, throughput capacity, speed, and traction (Buckmaster, 2009). Forage harvesters are designed for ease of harvesting, with a reduced share of human labor, in time, with an optimal length of chopping, acceptable losses and high throughput (Jonhson et al., 2002; Harrigan, 2003; Calvin, 2007; Mohammad et al., 2013).

Ensiling whole plants is rational when applied mechanization ensures proper distribution of the chopped material of suitable length from plants that are ensilaged to desired fractions (Ott, 2000; Lisowski, 2006; Van & Heinrichs 2008; Barać et al., 2014; Radojević et al., 2014).

Stanimirovic et al. (2004, 2008), reported that the increase in speed of the forage harvester from 2.86 km h⁻¹ to 3.64 km h⁻¹ increases losses from 2.34% to 4.85%, while increasing the cutting height from 13 cm to 21 cm results in losses increase from 2.54% to 5.15%. Set chopping lengths of 10 mm was achieved with 69.87%. Koprivica et al. (2009), reported that the increasing in the cutting height from 10 to 20 cm resulted in a decrease in the yield of 3 t ha⁻¹.

Analyzing the quality of the forage harvester Potkonjak et al. (2010), suggest that the lathe Krone BIG X-V8 achieved an average length of chopping 9.84mm (set length 10 mm), and silo-harvester John Deere 6810 length of 12.3 mm- set length of chopping 11mm.

MATERIAL AND METHOD

At the end of August 2014th the test were conducted in the vicinity of Kragujevac (44°04'60" N, 20°52'60" E), and included the assessment of the quality of the three self-propelled forage harvester: Claas Jaguar 675, Zmaj 350 and John Deere 5820.

All data were taken from the surface of 10 m² in 5 replications. On the plots hybrid maize was planted ZP-704. Based on the condition of crops, the length of chopping at the combine, was set to 8 mm.

Length of chopped mass was determined by sampling the chopped mass of the trailer for transport to an amount of 2 kg, followed by a subsequent measurement that was performed, and chopped mass was grouped by quality fractions.

Losses due to cutting height were measured on the basis of measurements of height cut off maize plants in relation to the set cutting height of 12 cm, the length of the 25 m of the working width of forage harvesting.

Based on this, the mass loss was determined due to the height of the cut-off stalks of the harvested yield as a consequence of the differences. Operating speed is determined by chronometer, and all values were taken from five repetitions.

Table 1 Technical data of examined field forage harvesters

Parameters		Type of forage harvesters		
		Claas Jaguar 675	John Deere 5820	Zmaj 350
Number of rows	[m]	4	4	3
Length	[m]	5.16	7.62	5.73
Width	[m]	2.62	3.30	2.51
Mass	[kg]	6,800	7,711	4,800
Chopping device type	/	Cylinder with knives	Cylinder with knives	Cylinder with knives
Drum rotations	[min ⁻¹]	1,000	1,200	1,100
Maximal capacity	[t h ⁻¹]	90	100	80
Cutting length	[mm]	4.1-28	3-20	4.8 -19
Operating speed	[km h ⁻¹]	up to 10	up to 10	up to 10
Transport speed	[km h ⁻¹]	20	20	20
Engine power	[kW]	127	206	125
The average plant height	[mm]	2,593	2,753	2,865
The average height set on ear	[mm]	761	754	768
Stem diameter	[mm]	25.30	24.13	23.98
Number of plants per hectare	[plant ha ⁻¹]	58,967	59,260	59,758
Yield of maize	[t ha ⁻¹]	25.76	26.12	25.94
Moisture	[%]	70.85	75.64	73.92
The average length of a clip	[mm]	263	256	271

Table 1 shows the basic data of the technical characteristics of the tested self-propelled forage harvesters and state maize on plots on which they performed the test.

Based on the data in table 1 it can be seen that the tested forage harvesters were working in similar production conditions. The average yield was in the range of 25.76 to 26.12 t ha⁻¹ and the average height of corn stalks were in the range 2,593-2,865 mm. Diameter of the stem at the cutting high was 23.98 - 25.30 mm, wherein the number of plants was in the range 58,967-59,758.

RESULTS AND DISCUSSION

Table 2 presents data on determined losses when working with investigated forage harvesters.

Based on the obtained results show that when harvesting with self-propelled silage Claas Jaguar 675 recorded average speed of 5.47 km h^{-1} was achieved with height of 21.18 cm, where losses are above 12 cm were averagely $1,201 \text{ kg ha}^{-1}$ or 4.66% in relation to realized yield. The lowest speed was 4.52 km h^{-1} , when minimum height was recorded of 19.16 cm, whereby realized losses were 988 kg ha^{-1} or 3.83%, which is the lowest value of the measured losses during tests of forage harvesters. In the work of this forage combine maximum speed was 6.41 km h^{-1} , with height of 22.95 cm achieved and losses of $1,420 \text{ kg ha}^{-1}$ or 5.51%.

When harvesting silage with silo-combine John Deere 5820 average speed of 5.91 km h^{-1} was achieved and cut height of 23.25 cm, with an average loss of $1,276 \text{ kg ha}^{-1}$ or 4.89% of the actual yield. The minimum speed during operation of the combine was 4.95 km h^{-1} , wherein the measured losses were $1,126 \text{ kg ha}^{-1}$ or 4.31%, and the maximum 6.98 km h^{-1} with a cutting height of corn stalks of 25.18 cm and losses of $1,468 \text{ kg ha}^{-1}$, 5.62% from the measured yield.

Analyzing the quality of the silage harvester Zmaj 350 it may be concluded that the achieved average speed was 5.61 km h^{-1} , cut height 22.69 cm and average losses $1,287 \text{ kg ha}^{-1}$ or 4.95%. At the lowest speed of 4.81 km h^{-1} cutting height of 20.45 cm and losses 4.22% or $1,096 \text{ kg ha}^{-1}$ were achieved.

Highest measured speed during operation of the silo-combine was 6.35 km h^{-1} , achieved by cutting height of 24.98 cm and losses of $1,549 \text{ kg ha}^{-1}$ or 5.97%, they are also the largest measured losses for all the harvesters (table 2).

Table 2 Realized losses on the work of examined forage harvesters

Type of ensilage harvesters	Speed [km h^{-1}]	Realized cutting height [cm]	Losses due to the amount of cut		Collected yield* [kg ha^{-1}]	Realized yield [kg ha^{-1}]
			[kg ha^{-1}]	[%]		
Claas Jaguar 675	4.52	19.16	988	3.83	24,775	25,763
	5.48	21.42	1,195	4.64	24,568	
	6.41	22.95	1,420	5.51	24,315	
Average	5.47	21.18	1,201	4.66	25,553	
John Deere 5820	4.95	21.10	1,126	4.31	24,994	26,120
	5.80	23.46	1,235	4.73	24,885	
	6.98	25.18	1,468	5.62	24,652	
Average	5.91	23.25	1,276	4.89	24,844	
Zmaj 350	4.81	20.45	1,096	4.22	24,845	25,941
	5.67	22.63	1,211	4.67	24,730	
	6.35	24.98	1,549	5.97	24,392	
Average	5.61	22.69	1,287	4.95	24,654	

*Collected yield- is a result of the decreased realized yield caused by the losses of the harvesters work

Similar results in their research are cited by other authors (Harrigan 2003; Stanimirović et al., 2004; Calvin 2007; Koprivica et al., 2009).

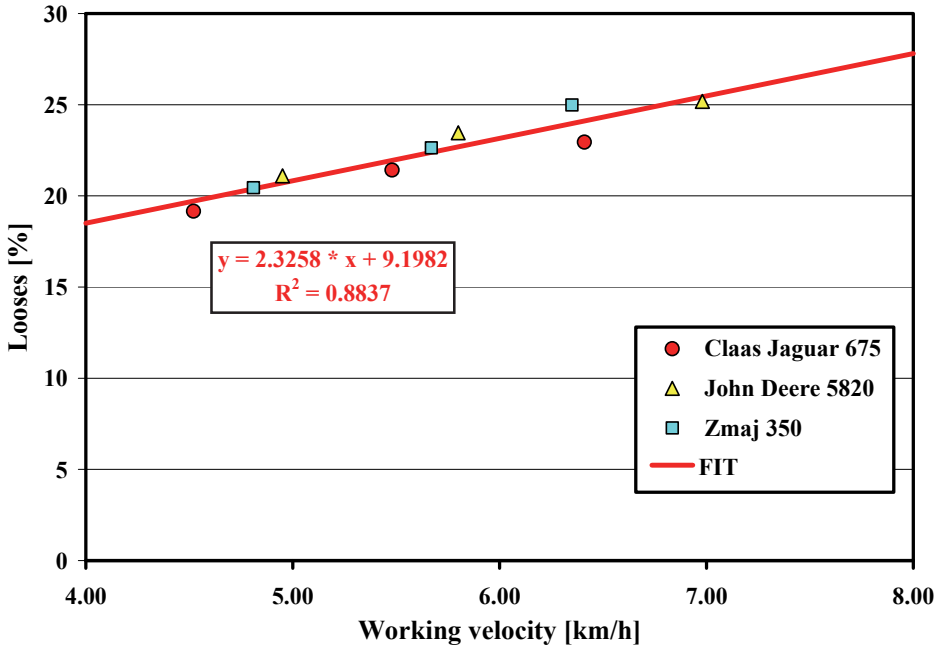


Figure 1 Relationship between working velocity of silage harvesters and losses caused by inappropriate cutting height

Figure 1 verifies the existence of clear relationship between working velocity of forage harvesters and losses caused by inappropriate cutting height. These two parameters are directly proportional, i.e. their connection is strong ($R^2 = 0.88$) and linear:

$$\text{Losses [\%]} = 2.3258 * \text{Velocity [km h}^{-1}\text{]} + 9.1982 \quad (1)$$

Previous equation is valid for all three tested silage harvesters in the whole tested range of harvester velocities, between 4.5 [km h⁻¹] and 7 [km h⁻¹].

The figure 2 shows the average values achieved chopping lengths depending on defined parameters, as well as the representation of fractions. Based on the results, it can be observed that when storing silage Class Jaguar 675 achieved average length of chopped mass of 9.97 mm with a standard deviation of 1.38. Most of the chopped mass was in the fraction of up to 10 mm and to 69.87%, and the fraction of 11-20 mm in length by 27.91%, and the content recorded in the smallest fractions of the mass chopped lengths was 20 mm and larger to 2.23% (Figure 2).

When storing silage with John Deere 5820 an average length of chopped mass of the 10.54 mm was achieved.

When the representation of the individual fractions in question, it is noted that the fraction of up to 10 mm was 64.90%, 31.97% by 11-20 mm and fraction lengths greater than 20 mm 3.13% (Figure 2) .

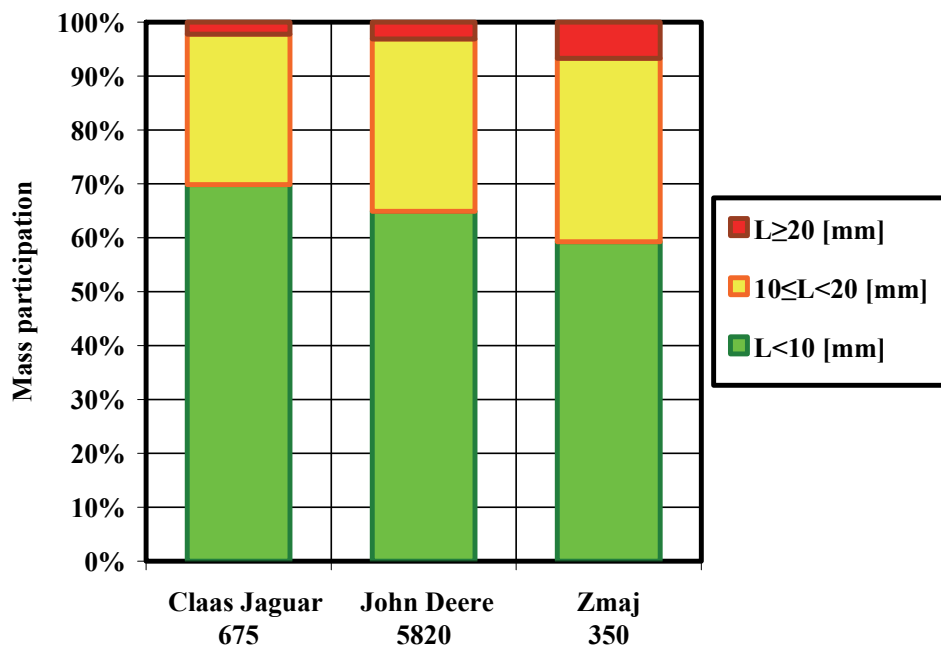


Figure 2 Cutting lengths distributions of forage particles, achieved by tested forage harvesters

The data in figure 2 show that when storing maize silage with the silo-combine Zmaj 350 it is measured that the average length of chopped mass of the 11.48 mm.

Most of the chopped mass during ensilage preparation the lathe there is a fraction of the length to 10 mm and to 59.27%, and the fraction of 11-20 mm in length by 34.02%, and the content recorded in the smallest fractions of the mass of chopped lengths greater than 20 mm, and that 6.71% (Figure 2).

These results are consistent with the results of their research cited out other authors (Ott, 2000; Jonhson et al, 2002; Lisowski, 2006; Calvin 2007; Stanimirović et al., 2008; Van & Heinrich, 2008; Potkonjak et al., 2010; Radojević et al., 2014).

Figure 3 presents comparison of the mean cut lengths of maize silage particles, achieved by tested combines. Results presented in this figure confirm the supremacy of silage harvester Class Jaguar 675 in comparison to other two tested machines.

Absolute deviation of these mean values with respect to preset cut length of 8 [mm] are shown also. In general, all three harvesters achieved fairly acceptable cut lengths of harvested corn particles, including the long used forage harvester Zmaj 350.

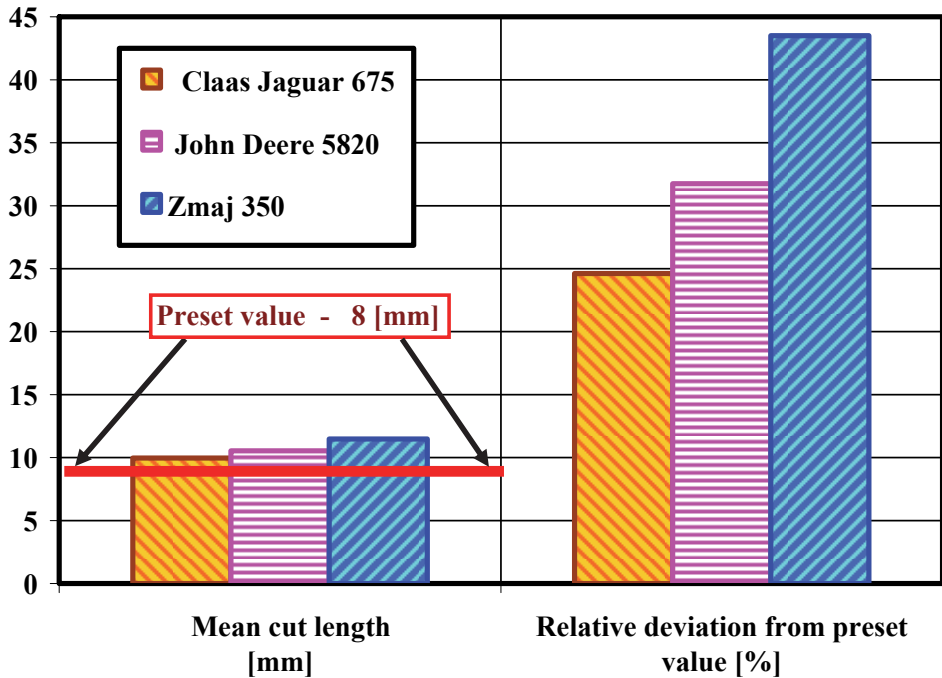


Figure 3 Mean cutting lengths of forage particles and their percentual deviations from the preset value of cutting length (8 [mm])

However, experimental results verify the operational supremacy of modern harvesters Class Jaguar 675 and John Deer 8520 with relation to the long used forage harvester Zmaj 350.

CONCLUSIONS

Based on these results, we can conclude that the tested forage harvesters working in similar production conditions yielding mass of corn from 25.76 to 26.12 t ha⁻¹, average height of corn stalks from 2,593-2,865 mm, stem diameter of 23.98 – 25.30 mm and moisture of plant material from 70.85-75.64%. The cutting height varied in the range of 19.16 cm in silage harvester Class Jaguar 675, up to 25.18 cm in silage harvester John Deer 5820. The realized losses were in the range of 988 kg ha⁻¹ or 3.83% as compared to the biological yield when working with silage harvester Claas Jaguar 675, up to 1,549 kg ha⁻¹ or 5.97 % when working with silage harvester Zmaj 350. With the increase of operating speed for all test harvesters height of cut and losses due to the height of cut were increasing. All harvesters were chopping ground corn with good quality logs cob and corn kernels. The minimum deviation of achieved long chopped mass in relation to the setting were recorded when storing silage with silage harvester Claas Jaguar 675 in which the average length of chopped mass was 9.97 mm, wherein in a fraction of up to 10 mm was 69.87%, the fraction of the length 11-20 mm 27.91%, while the lowest content was recorded in the mass

fraction chopped lengths greater than 20 mm or 2.23%. Silage harvester Zmaj 350 had lowest performance having in mind that it achieved average length of chopped mass of 11.48 mm, wherein the length of the fraction of 10 mm was 59.27%, then the fraction of the length of 11-20 mm was 34.02%, whereas the mass of the fraction of chopped lengths greater than 20 mm was 6.71%.

ACKNOWLEDGEMENT

The investigation published in this paper is a part of the project "Improvement of biotechnological procedures as a function of rational utilization of energy, agricultural products productivity and quality increase" financed by the Ministry of Education and Science of the Republic of Serbia, grant No TR-31051.

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HIGH PRECISION WITH REAL TIME CORRECTION IN MANUFACTURING

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ABSTRACT

All that structures that are applied to static or dynamic loads are reacting in multiple ways, the main issue that is interesting for precision of manufacturing being the changes in the shape of the structure that are taking place during the process. Attempting to reach the ideal of zero errors we propose a system that is able to correct in real time the errors.

Key words: structures, static load, dynamic load, precision, manufacturing, correction, ideal shape and dimension.

INTRODUCTION

A simple solution to get higher precision in manufacturing is to increase the loading capacity of the structure in order to minimize the deformations. [1],

This simple way of judging things is the easiest but on the costs will be increased also, and on long term the solution is not acceptable due to the small plastic deformation that are present in every elastic deformation, on long term their cumulated effects will affect the precision of the whole structure of the machine, so we will get a bad precision as a result.[2], [5]

The opposite point of view takes in consideration that it is not inconvenient the fact the structure is changing itself as dimensions and basic shape if we can determine the exact value of deformation in the cross section where the tool is working. [4], [8], [11].

METHODS

Knowing the value of deformation, give us the possibility to compensate the errors by ordering to the machine corrective movements with the goal of getting zero errors that means maximum precision. [6]

In theory the things are looking to be very clear and easy, but when applying them in tool machinery engineering they are becoming quite complicated. [3],

The main problem to solve is how can be calculated the value of deformation is the cross section of the tool? The answer to this question requires not classic material resistance methods but methods that can deal with multiple non-determined in the system of equations that can be attached to the model.

An example of applying of the classic methods (Figure 1) for a turning machine follows:

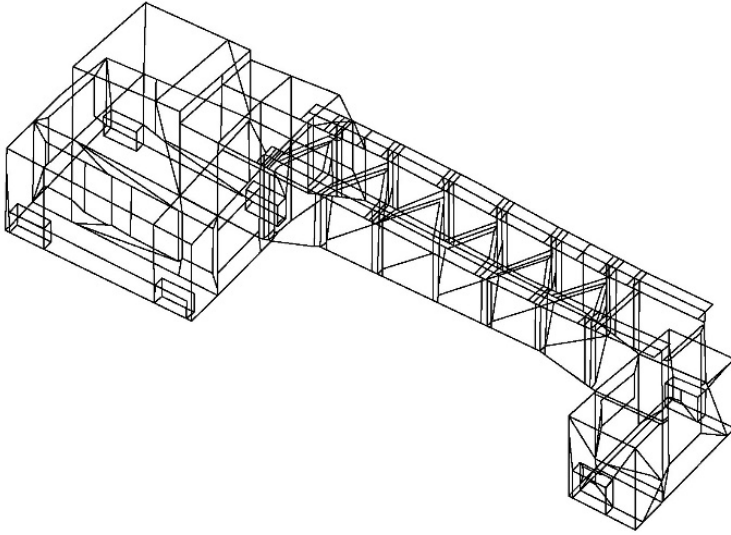


Figure 1 Classic methods of calculating forces

Classic methods are using the six equations of equilibrium that we can apply: three equations of forces along the three axes of the reference system and another three equations of torques around the axes. Those six equations are completely nonsufficient, the number of unknown parameters being at least eight. [7], [10]

Classic Solutions

We know the value of the forces (calculated with the parameters of cutting process) and we can write the following equations (1-6), [3], [6] :

$$\sum F_x = 0 \rightarrow Q = F_f + F_{fr} \quad (1)$$

$$\sum F_y = 0 \rightarrow R_{T1} + R_{T2} + R_1 = F_p \quad (2)$$

$$\sum F_z = 0 \rightarrow F_c + G = R_2 \quad (3)$$

$$\sum M_x = 0 \rightarrow G y_G + R_1 z_{R1} = R_{T1} z_{RT1} + R_{T2} z_{RT2} + R_2 y_{R2} - F_p z_{Tp} + F_c y_c \quad (4)$$

$$\sum M_y = 0 \rightarrow F_f z_{Ff} + R_2 x_{R2} + F_{fr} z_{Ffr} = Q z_Q + F_c x_{Fc} - G x_G \quad (5)$$

$$\sum M_z = 0 \rightarrow F_f z_{Ff} + R_1 x_{R1} + R_{T1} x_{RT1} = Q y_Q - F_{fr} y_{Ffr} + F_p y_{Tp} + R_{T2} x_{RT2} \quad (6)$$

In order to have a full determined equation system we must find another two equations.

In classic resistance material methods, if we can find a type of structure that due to its particularity in shape and functionality, the results will look like (7-19):

$$f = \frac{\sqrt{M_{2v}^2 + M_{2H}^2}}{E \left(\frac{BH^3}{12} + a_2^2 BH + \frac{bh^3}{12} - a_3^2 bh \left(\frac{\pi}{8} - \frac{8}{9\pi} \right) \frac{B^4}{16} + a_1^2 \frac{\pi B^2}{8} \right)}$$

$$= \frac{\frac{1-x_2}{1} \sqrt{F_1^2 x_1^2 + F_2^2 x_2^2 + 2F_1 F_2 x_1 x_2 \cos \alpha}}{E \left(\frac{BH^3}{12} + a_2^2 BH + \frac{bh^3}{12} - a_3^2 bh \left(\frac{\pi}{8} - \frac{8}{9\pi} \right) \frac{B^4}{16} + a_1^2 \frac{\pi B^2}{8} \right)} \quad (7)$$

$$\varphi = \frac{T_f}{EI_z} \quad (8)$$

$$\varphi = \frac{\frac{F_1 x_1 + F_2 x_2 \cos \alpha}{1}}{E \left(\frac{BH^3}{12} + a_2^2 BH + \frac{bh^3}{12} - a_3^2 bh \left(\frac{\pi}{8} - \frac{8}{9\pi} \right) \frac{B^4}{16} + a_1^2 \frac{\pi B^2}{8} \right)} \quad (9)$$

$$\theta = \frac{M_1}{G I_p} \leq \theta_a \left[\frac{\text{rad}}{\text{m}} \right] \quad (10)$$

$$\theta = \frac{F_2 \left[\frac{H - \frac{BH^2}{2} - bh \left(\frac{h}{2} + h_2 \right) + \frac{\pi B^2}{8} \left(H + \frac{2B}{3\pi} \right)}{BH - bh + \frac{\pi B^2}{8}} \right] \sin \alpha}{G \left(\frac{BH^3}{12} + a_2^2 BH + \frac{bh^3}{12} - a_3^2 bh \left(\frac{\pi}{8} - \frac{8}{9\pi} \right) \frac{B^4}{16} + a_1^2 \frac{\pi B^2}{8} \right)} \quad (11)$$

$$R_{T1} = F_p \frac{\frac{L_{Fp}}{z_{Fp}} - \frac{L_{RT2}}{z_{RT2}}}{z_{RT1}} \quad (12)$$

$$R_{T1} = F_p \frac{L_{Fp}}{L_{RT_2}} \quad (13)$$

$$R_1 = F_p \frac{L_{RT_2}(z_{RT_1} - z_{Fp}) - L_{Fp}(z_{RT_1} + z_{RT_2})}{L_{RT_2} z_{RT_1}} \quad (14)$$

$$R_2 = F_c + G \quad (15)$$

$$Q = F_f + \mu(F_c + G) \quad (16)$$

$$x_{R_2} = \frac{Qz_Q + F_c x_{Fc} - G x_G - F_f z_{Ff}}{F_c + G} \quad (17)$$

$$y_{R_2} = \sqrt{r^2 - z_{R_1}^2} \quad (18)$$

$$z_{R1} = \frac{-F_p \frac{L_{RT_2}(z_{RT_1} - z_{Fp}) - L_{Fp}(z_{RT_1} + z_{RT_2})}{L_{RT_2} z_{RT_1}} (G y_G + 2 F_p \frac{L_{Fp}}{L_{RT_2}} z_{RT_2} - F_c y_{Fc})}{\sqrt{F_p^2 \left[\frac{L_{RT_2}(z_{RT_1} - z_{Fp}) - L_{Fp}(z_{RT_1} + z_{RT_2})}{L_{RT_2} z_{RT_1}} \right]^2 + (G y_G + 2 F_p \frac{L_{Fp}}{L_{RT_2}} z_{RT_2} - F_c y_{Fc})}} \quad (19)$$

Improving Classic Solutions

Now, the big problem is just beginning because we cannot write supplementary equations that are 100 % sure but we can consider only some equations that are coming from the practice experience that means they have just a probability to be sure. In fact if we are adding two of those types of equations we need a third one that will confirm or not our suppositions (equations coming from practice experience). [9], [11]

As you probably notify it is beginning now to look like an algorithm, that it is in fact, in conclusion we can determine a logic process (Figure 2).

Now we can declare the problem solved if the third equation fulfills the conditions of the other two, if not we must initiate the process again, changing a little bit the first two equations and repeating the procedure.

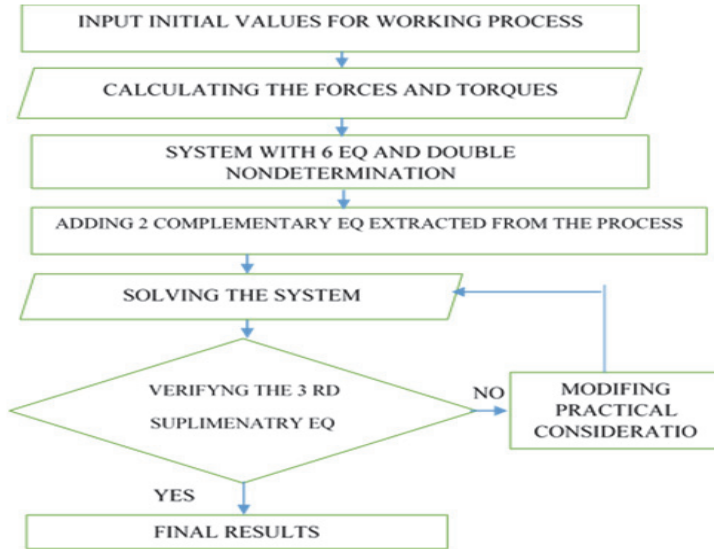


Figure 2 Logical process

RESULTS AND DISCUSSION

Using this logic we can obtain or not the results in real time, everything depending on the inspiration of choosing the supplementary equations.

We know that the finite element method is the right solution but to use it is another discussion, the method being applied to calculate structures that are let say “static”, or our case suppose almost instantaneous calculation and then instantaneous corrective action from the machine, things that are not possible basic because of two problems:

1. We do not have a strong enough software and the very strong computer to be able to apply the method in real time (time enough for the machine to take the result and make the correction);
2. We do not have mechanical systems on the machine to do the correction in real time, most of them, classic used, being too slow. [8]

For example for the structure mentioned above the finite element method will show in Figure 3.

In fact we can't use the method in real time, and in order to obtain some advantages from the excellent precision that the finite element method is offering us we can proceed as follows Figure 4.

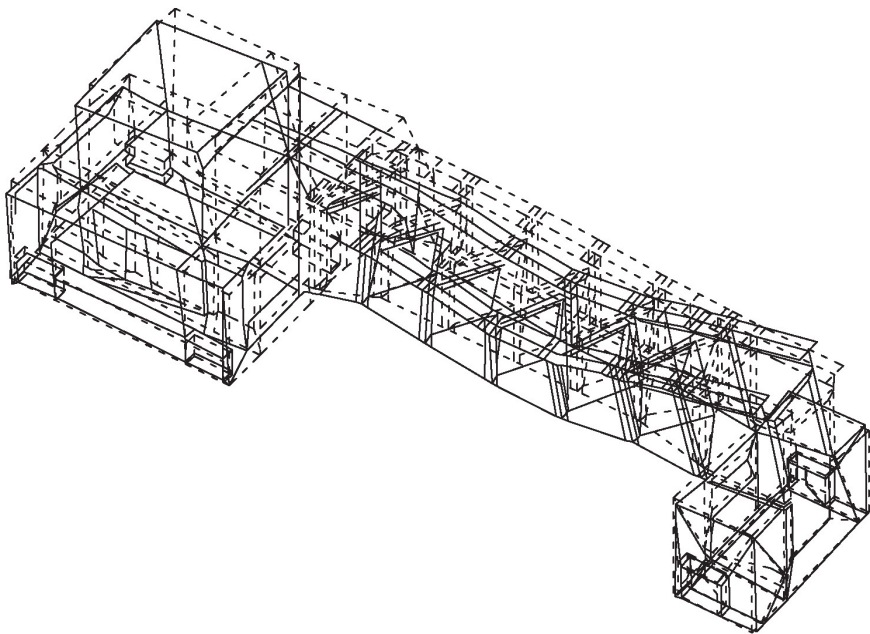


Figure 3 Finite element method

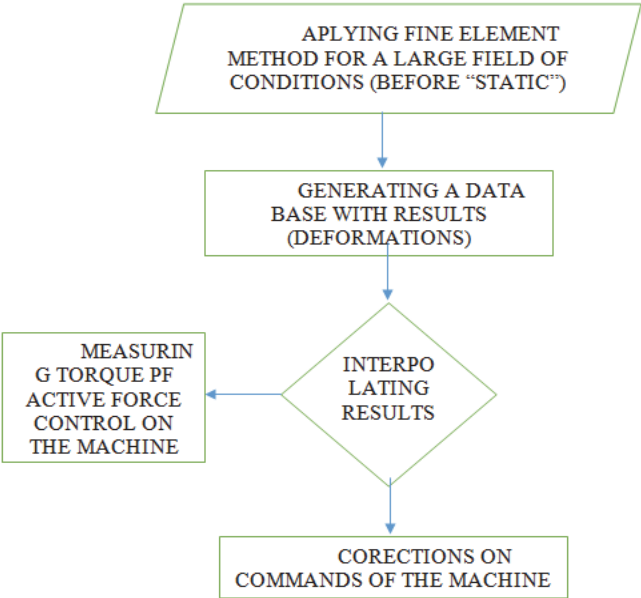


Figure 4 Logical Algorithm

1. We describe our structure as requested to be used by the finite element method;
2. Based on the parameters of process we can calculate the range of stress that the structure will be exposed at;
3. Choosing a convenient step we will apply the method step by step covering the whole interval;
4. The results (deformations) will be organized in a data base;
5. On the manufacturing process we will follow the variation of only one parameter, in order to accelerate the algorithm, that parameter being in the case of a turning machine the principal cutting force, controlled by the adaptive force control device of the machine;
6. For speeding the process we will use not the function of force that is coming out from the device like information but the first or even the second derivate of this function that offers us a predictability of the evolution for the force;
7. Having this information we can go now to the data base of deformation and making an interpolation of the values of forces we can approximate acceptably the deformation;
8. Already deformation accepted we can command a very fast reaction on the machine in order to compensate it using non-conventional sources of movement (engines) like the magnetostrictive engine having the principal advantage the very short time of reaction. A similar reaction can be obtained using hydraulic systems as shown in the Figure 5.
9. The algorithm of points 1 to 8 can be concluded in the picture (Figure 4).

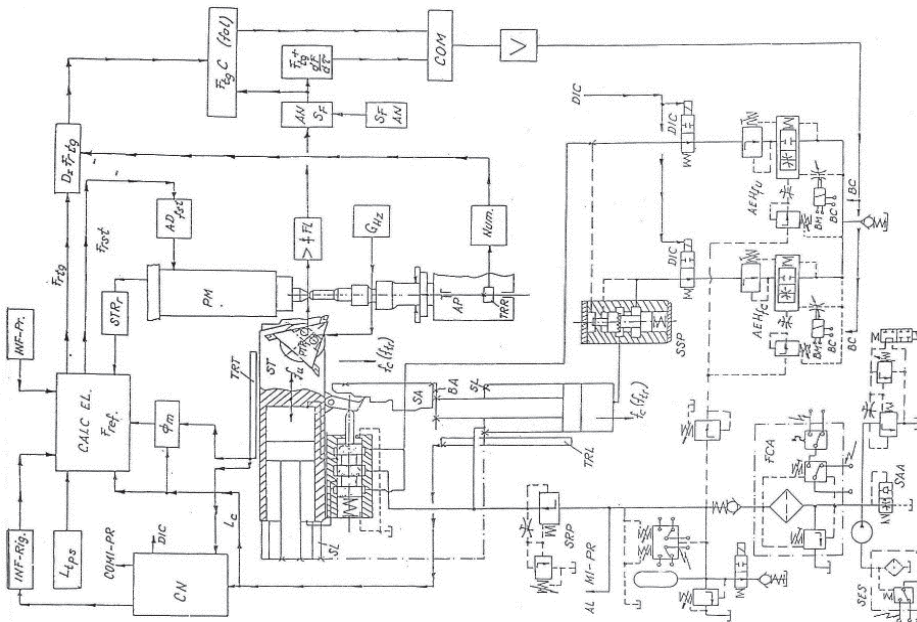


Figure 5 Hydraulic system

CONCLUSIONS

Depending on the particular situation both classic or modern methods can be applied, the results are very much influenced by the way the engineer manages to extract mathematic information's from the manufacturing process.

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VIBRATORY MOVEMENT ANALYSIS OF PLANSIFTERS FROM MILLING PLANTS

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ABSTRACT

In the paper, is studied based on the model of rigid body elastically suspended, vibrations circular translation movement of plansifters from milling plants. Dynamic calculus is done using Lagrange equations, on the assumption that the system is fully centred. Analytical solutions of differential equations lead to the law of variation of the vibration amplitude and velocity points of plansifters. These depend on the stiffness of the suspension system, eccentricity of mass vibration generator and its size. Is identified the phenomenon that is taking place dynamic balance. Based on the obtained relations was developed a numerical calculation for a Romanian plansifter, confirming the theoretical and experimental data.

The study presented may be of interest for specialists in design, construction and operation of plansifters on the workflow of milling plants.

Key words: plansifters, mechanical vibrations, vibration generator, dynamic balancing

INTRODUCTION AND LITERATURE REVIEW

In scientific literature [7,8,13], it is estimated that the process of sorting by sifting is very familiar and apparently simple, but actually, the process is extremely complex with a number of variables that can lead to erroneous data in sifting process analysis as well of equipment designing. Currently, [9,10], plansifters motion study is made based on Newtonian mechanics methods. Using methods of analytical mechanics and of vibration theory leads to highlighting specific issues.

Plansifters for sifting and sorting of grist products in units for the production of wheat flour must provide a plane circular translational motion for all sieve frames.

Actuation of equipments and their balancing is most often carried out with mechanisms provided with centrifugal unbalanced masses in rotational motion, carrying out a circular movement of sieve frames to a radius of the trajectory at an adjustable value.

In general, plansifters are actuated through actuating mechanisms which allow a circular translation movement, each plansifter point describing a circle, [4,11,14].

In addition, in paper [6] it highlights the fact that during equipment start up, circle radius of movement of the plansifter, in transient regime, perceptible increase until revolution speed of the actuating mechanism passes in the resonance area and optimum revolution speed is reached. Thus, a heavy weight of equipment leads to a high start-up time and invariably to a high energy consumption.

To cover some of these deficiencies, lately there has been appeared a new solution [16], whose mechanism is analysed in detail in the papers [2,3]. Thus, during operation, at a time, inertial forces applied perpendicular on the axes of sieve blocks, balance each other. Still, due to the eccentricity of the actuating mechanism, remains a torsional moment, around the main shaft, is equal to $2mr_1\omega^2$, where m is the mass of a compartment. This moment can be compensated (balanced) through an elastic system mounted between two support plates which solidary pairs of cylinders.

PHYSICAL AND MATHEMATICAL MODEL OF PLANSIFTER

Identification of essential elements for plansifter vibration study is made on the illustration in fig. 1.

Thus, is distinguished plansifter framework 1, suspended through elastic bars of the same length 2 and the vibration generator 3. The assembly plansifter-vibration generator is mounted so that the centre of mass C of the assembly remain on axis of vibration generator. For plansifters performed according to sketch in fig 1 is allowed the following assumptions:

- a) vibrating machine constitutes a system fully centred, i.e. resultant of perturbing, elastic and dissipative forces passes through the centre of mass of the system. The consequence of this hypothesis is that working bodies performs translational movement.
- b) electric motor has sufficient strength such that the interaction of motor-vibrating machines is negligible. It follows that the functioning of the machine in stationary regime is made with constant angular velocity.
- c) is neglecting the mass effect of the elastic elements and their nonlinear effects.
- d) is neglecting the effect of weight and displacement of the environment in contact with working bodies. This can be done when weight of the material is less than that of working body.
- e) system movement occurs around the stable equilibrium position.
- f) dissipative forces is considered proportional to the speed of the working bodies

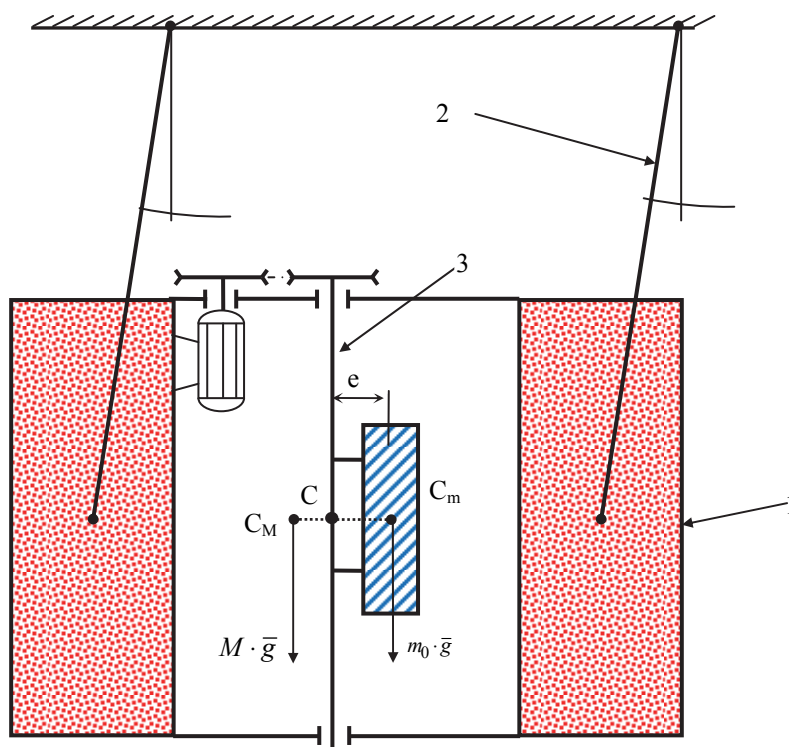


Fig. 1 Schematic representation of plansifter with vibration generator

Based on the assumptions mentioned, assembly plansifter-vibration generator represented in fig.1 is reduced to the physical model from fig. 2 for which are made the following notation:

M - mass of mobile system (framework, sieve, vibration generator), less the unbalanced mass;

m_0 – eccentric mass (unbalanced);

e - unbalanced mass eccentricity (the radius of rotation of counterweights);

Ω - angular velocity (constant) of unbalanced mass;

k_x and k_y - equivalent stiffness constants in the transverse direction Ox and Oy of suspending bars;

c_x and c_y - damping constants of the system corresponding to transverse displacements along Ox and Oy .

The system being centered, is hypothesized that main directions of elastic forces coincide with those of damping forces, and the latter being commensurate with the displacement speed.

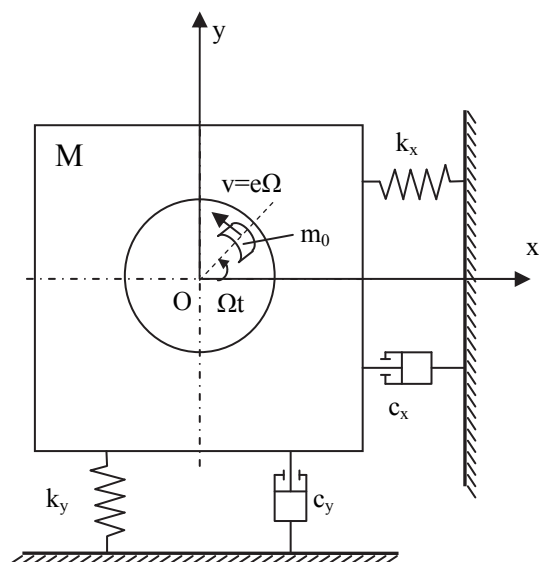


Fig. 2 The physical model of the plansifter with vibration generator

For the determination of differential equations of movement is used Lagrange's equations of the second order in the form of:

$$\frac{d}{dt} \left(\frac{\partial E}{\partial \dot{q}_k} \right) - \frac{\partial E}{\partial q_k} = \frac{\partial U}{\partial q_k} + Q_k, \quad (k = 1, 2) \quad (1)$$

where: E is the kinetic energy of the system; U – force function corresponding to conservative forces; Q_k – generalized forces, other than conservative forces; q_k , $\dot{q}_k$ – generalized coordinates, respectively generalized velocities.

Are chosen as generalized coordinates displacement on the axis directions Ox and Oy , respectively $q_1=x$ and $q_2=y$.

Then, the kinetic energy of the system (fig. 2) is:

$$E = \frac{1}{2} \cdot M \cdot \dot{x}^2 + \frac{1}{2} \cdot m_0 \cdot (\dot{x} - \Omega \cdot e \cdot \sin \Omega t)^2 + \frac{1}{2} \cdot M \cdot \dot{y}^2 + \frac{1}{2} \cdot m_0 \cdot (\dot{y} + \Omega \cdot e \cdot \cos \Omega t)^2 \quad (2)$$

Force function is:

$$U = -\frac{1}{2} \cdot k_x \cdot x^2 - \frac{1}{2} \cdot k_y \cdot y^2 \quad (3)$$

Dissipative forces are proportional to displacement velocities and it follows that: $F_x^d = -c_x \cdot \dot{x}$, and $F_y^d = -c_y \cdot \dot{y}$. Then using the principle of virtual powers results:

$$\begin{aligned} Q_1 &= \frac{P_1^v}{\dot{x}} = \frac{(-c_x \cdot \dot{x}) \cdot \dot{x}}{\dot{x}} = -c_x \cdot \dot{x} \\ Q_2 &= \frac{P_2^v}{\dot{y}} = \frac{(-c_x \cdot \dot{y}) \cdot \dot{y}}{\dot{y}} = -c_x \cdot \dot{y} \end{aligned} \quad (4)$$

It is also calculated:

$$\begin{cases} \frac{\partial E}{\partial \dot{x}} = M \cdot \dot{x} + m_0 (\dot{x} - \Omega \cdot e \cdot \sin \Omega t) \\ \frac{\partial E}{\partial \dot{y}} = M \cdot \dot{y} + m_0 (\dot{y} + \Omega \cdot e \cdot \cos \Omega t) \end{cases} \quad (4)$$

$$\begin{cases} \frac{d}{dt} \left(\frac{\partial E}{\partial \dot{x}} \right) = M \cdot \ddot{x} + m_0 (\ddot{x} - \Omega^2 \cdot e \cdot \cos \Omega t) \\ \frac{d}{dt} \left(\frac{\partial E}{\partial \dot{y}} \right) = M \cdot \ddot{y} + m_0 (\ddot{y} - \Omega^2 \cdot e \cdot \sin \Omega t) \end{cases} \quad (5)$$

$$\frac{\partial E}{\partial x} = \frac{\partial E}{\partial y} = 0 \quad \frac{\partial U}{\partial x} = -k_x \cdot x ; \quad \frac{\partial U}{\partial y} = -k_y \cdot y \quad (6)$$

After calculations, differential equations takes the form:

$$\begin{cases} (M + m_0) \cdot \ddot{x} + c_x \cdot \dot{x} + k_x \cdot x = m_0 \cdot \Omega^2 \cdot e \cdot \cos \Omega t \\ (M + m_0) \cdot \ddot{y} + c_y \cdot \dot{y} + k_y \cdot y = m_0 \cdot \Omega^2 \cdot e \cdot \sin \Omega t \end{cases} \quad (7)$$

If it divides with $(M+m_0)$ and are used the corresponding notations, [5,12], equations (7) takes the form:

$$\begin{cases} \ddot{x} + 2 \cdot \varsigma_x \cdot \omega_{0x} \cdot \dot{x} + \omega_{0x}^2 \cdot x = q \cdot \cos \Omega t \\ \ddot{y} + 2 \cdot \varsigma_y \cdot \omega_{0y} \cdot \dot{y} + \omega_{0y}^2 \cdot y = q \cdot \sin \Omega t \end{cases} \quad (8)$$

where:

$$\begin{aligned} \varsigma_x &= \frac{c_x}{2(M + m_0) \cdot \omega_{0x}} ; \varsigma_y = \frac{c_y}{2(M + m_0) \cdot \omega_{0y}} \\ \omega_{0x}^2 &= \frac{k_x}{M + m_0} ; \omega_{0y}^2 = \frac{k_y}{M + m_0} \\ q &= \frac{m_0 \cdot e \cdot \Omega^2}{M + m_0} = \frac{F_0}{M + m_0} \end{aligned} \quad (9)$$

Solutions corresponding to permanent working regime, [5,12], are:

$$\begin{cases} x = A_{0x} \cdot \cos(\Omega t - \varphi_x) \\ y = A_{0y} \cdot \sin(\Omega t - \varphi_y) \end{cases} \quad (10)$$

where the movement amplitude on the two directions is:

$$A_{0x} = \frac{m_0 \cdot e \cdot \Omega^2 / (M + m_0)}{\sqrt{(\omega_{0x}^2 - \Omega^2)^2 + (2 \cdot \zeta_x \cdot \omega_{0x} \cdot \Omega)^2}}; A_{0y} = \frac{m_0 \cdot e \cdot \Omega^2 / (M + m_0)}{\sqrt{(\omega_{0y}^2 - \Omega^2)^2 + (2 \cdot \zeta_y \cdot \omega_{0y} \cdot \Omega)^2}} \quad (11)$$

In relations (11) if is given common factor ω_{0x}^2 , respectively ω_{0y}^2 and is noted $r_x = \Omega / \omega_{0x}$ and $r_y = \Omega / \omega_{0y}$ results that:

$$A_{0x} = \frac{(m_0 \cdot e \cdot r_x^2) / (M + m_0)}{\sqrt{(1 - r_x^2)^2 + (2 \cdot \zeta_x \cdot r_x)^2}}; A_{0y} = \frac{(m_0 \cdot e \cdot r_y^2) / (M + m_0)}{\sqrt{(1 - r_y^2)^2 + (2 \cdot \zeta_y \cdot r_y)^2}} \quad (12)$$

With the above notation, phase difference is calculated with relations, [5,12]:

$$\operatorname{tg} \varphi_x = \frac{2 \cdot \zeta_x \cdot r_x}{1 - r_x^2}; \operatorname{tg} \varphi_y = \frac{2 \cdot \zeta_y \cdot r_y}{1 - r_y^2} \quad (13)$$

In the case in which, amortization in the system are negligible, i.e. $\zeta_x = \zeta_y \approx 0$, respective $\zeta_x = \zeta_y \approx 0$ from relations (11) results:

$$A'_{0x} = \frac{m_0 \cdot e \cdot \Omega^2}{k_x (1 - r_x^2)}; A'_{0y} = \frac{m_0 \cdot e \cdot \Omega^2}{k_y (1 - r_y^2)} \quad (14)$$

For r_x and $r_y \in [0;1)$ $\varphi_x = \varphi_y = 0$, i.e. system vibrates in phase, and for r_x and $r_y \in (1;\infty)$ $\varphi_x = \varphi_y = \pi$, i.e. system vibrates in phase opposition.

As a result, in the case without damping, solutions of differential equations for permanent working regime for r_x and $r_y \in [0;1)$ are written:

$$\begin{cases} x = A'_{0x} \cdot \cos \Omega t \\ y = A'_{0y} \cdot \sin \Omega t \end{cases} \quad (15)$$

And for r_x and $r_y \in (1; \infty)$ are written:

$$\begin{cases} x = -A'_{0x} \cdot \cos \Omega t \\ y = -A'_{0y} \cdot \sin \Omega t \end{cases} \quad (16)$$

If is eliminated time from the last two equations results:

$$\frac{x^2}{A'^2_{0x}} + \frac{y^2}{A'^2_{0y}} = 1 \quad (17)$$

Furthermore, for $k_x = k_y = k$ and so $r_x = r_y = r = (\Omega/\omega_0)$ results $A'_{0x} = A'_{0y} = A_0$ and so equation (17) is written:

$$x^2 + y^2 = A_0^2 \quad (18)$$

where

$$A_0 = \frac{m_0 \cdot e \cdot \Omega^2 / k}{|1 - r^2|} \quad (19)$$

It follows that all points of plansifter describe circles of radius A_0 and all have the same velocity $v = A_0 \cdot \Omega$, due to translational motion.

For $r^2 \gg 1$ can be approximated $|1 - r^2| \approx r^2$ and how $r = \Omega / \omega_0$ from relation (19) results:

$$A_0 \approx \frac{m_0 \cdot e \cdot \omega_0^2}{k} \quad (20)$$

So, at angular velocities large enough of the generator compared to its own pulsation ω_0 of the system, for a given plansifter the amplitude of vibrations remain constant in significant limits of variations of the vibration generator revolution speed. But the velocities of sieves points $v = A_0 \cdot \Omega$ (same for all plansifter) depend on the angular velocity of the vibration generator. Condition of optimal sifting of plansifters is limiting upper and lower the velocity of plansifter points, [10,11,14]. As a result, vibration generator revolution speed can vary within wide limits depending on the nature and condition of the sifting material.

On the other hand, for $r \gg 1$, phase difference take the value $\varphi = \pi$. This means that the position of the centre of mass C_M of sieve blocks and centre of mass C_{m_0} of eccentric mass

is in symmetric position with the centre of mass C of the entire system and so with axis of vibration generator (fig. 3). The two centres of mass are moving on the concentric circles with the centre in C . In this way occurs the dynamic balancing of the sifting system.

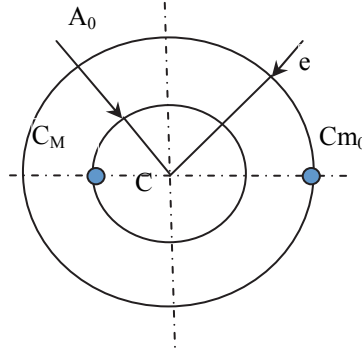


Fig. 3 Trajectories described by the center of mass of the eccentric mass C_{m_0} and the center of mass of the sieve blocks C_M

NUMERICAL APPLICATION

Plansifter, model SPP 420, made by TEHNOPAM Bucharest, is formed by four sifting compartments, each compartment comprising 20 frames. It is equipped with a vibration generator with unbalanced masses and have the sieve block mass $M=1610$ kg. Unbalanced mass $m_0 = 345$ kg, is placed eccentrically to the axis of rotation at $e=260$ mm and is rotating with revolution speed $n=220$ rot/min. Sieves block is suspended in four points with elastic bars made from boiled beech, length of one bar being $l=1450$ mm, diameter being $d=12$ mm and its elastic modulus $E=10^4$ N/mm². Elastic bars are in a number of $z=32$, i.e. in each of the four suspension points are 8 bars.

Axial moment of inertia of a bar:

$$I = \frac{\pi \cdot d^4}{64} = \frac{\pi \cdot 12^4}{64} = 1018 \text{ mm}^4$$

Constant stiffness of a bar is:

$$k_1 = \frac{12 \cdot E \cdot I}{l^3} = \frac{12 \cdot 10^4 \cdot 1018}{1450^3} \cong 0,04 \text{ N/mm} = 40 \text{ N/m}$$

Constant stiffness of the suspension system is:

$$k = z \cdot k_1 = 32 \cdot 40 = 1280 \text{ N/m}$$

Own pulsation:

$$\omega_0^2 = \frac{k}{M + m_0} = \frac{1280}{1610 + 345} = 0,65473 \Rightarrow \omega_0 \cong 0,81 \text{ rad/s}$$

Angular velocity of unbalanced mass:

$$\Omega = \frac{\pi \cdot n}{30} = \frac{\pi \cdot 220}{30} \cong 23,04 \text{ rad/s}$$

Pulsation ratio:

$$r = \frac{\Omega}{\omega_0} = \frac{23,04}{0,81} = 28,44$$

Unbalanced mass inertia force:

$$F_0 = m_0 \cdot e \cdot \Omega^2 = 345 \cdot 0,26 \cdot 23,04^2 = 47616,49 \text{ N} \cong 4762 \text{ daN}$$

Amplitude of vibration:

$$A_0 = \frac{F_0 / k}{|1 - r^2|} = \frac{47616 / 1280}{|1 - 28,44^2|} = 0,04609 \text{ m} = 46 \text{ mm}$$

CONCLUSIONS

From the numerical data, it follows that every point of the plansifter, under the conditions specified, describe a circle with radius of 46 mm, while the center of mass of the counterweight mass describe a circle with a radius of 260 mm. Center of mass motion of the sieves block is made in phase opposition to the movement of the eccentric mass m_0 and takes place on concentric circles relative to the center of mass of the entire assembly (fig. 3), because $r = 28,4$ mm, i.e. $r \in (1; \infty)$. Dynamic balance is carried out in condition in which $r \gg 1$, i.e. the system is in functioning in phase opposition.

The algorithm presented is useful to technologists and builders from the milling industry to assess radius of motion circle of a point on the plansifter, during functioning.

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MATHEMATICAL MODELS FOR DESCRIBING SEEDS MOTION IN SEPARATION PROCESSES

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SUMMARY

In this paper is presented the development of mathematical models for describing the seeds movement in the work process of the separating machines on electromagnetic way, respective the movement on drum and movement in the free flight of the smooth surface seeds.

The mathematical model for smooth seeds movement on cylindrical drum surface in rotating movement is developed, determining the position and separating speed from the drum of the seeds.

It is theoretical analyzed the trajectory in free flight of the smooth seeds from the drum, taking in consideration air resistance and it is evaluated the position of the collecting place of the detached seeds.

Case studies have been also performed and analyzed, on the base of numerical applications, the seeds movement for three different existing machines.

Numerical simulation of mathematical models provided information regarding seeds movement on drum and in free flight for assessment of the place of fall for collecting, useful elements in theoretical substantiation of work process of the machine.

Key words: seeds, magnetic separation, cinematic parameters, trajectory.

INTRODUCTION

The magnetic separation techniques find large and diverse applications in fields such as minerals industry, textile, plastics, for processing ceramic and food products.

The first applications can be found beginning with the 18th century and up to the 19th century for the separation of iron ores, and they make a significant development at the beginning of century XX, in Sweden (in 1906 the first wet magnetic separator is achieved) [7].

A wide range of techniques and equipment of magnetic separation have been developed, which are available both for the applications in various industries (especially in industry of minerals and processing of ceramics), and in the technologies field for processing agricultural products.

In this field equipment for magnetic separation has been developed, with the purpose of ensuring the safety of subsequent processing of the product, but especially with the purpose of obtaining the intrinsic quality of the product subject to cleaning operation.

Numerous theoretical and experimental studies have been enshrined to the phenomenon of magnetic separation in the industry of minerals and processing ceramics, which have been materialized in developing various types of modern and performant equipment in the field, as well as numerous papers and articles published [7].

Magnetic separation has also been applied in the cleaning processes of clover and alfalfa seeds of weed seeds, especially in those of the dodder seeds.

As a principle, the magnetic separation of the seeds consists in their property to be covered in fine iron powder, due to their porous integument, contrary to the smooth integument of seeds of clover and alfalfa at which the powder do not adhere, only accidentally and insignificantly.

For a successful application of the magnetic separation method special machines are used, equipped with electromagnetic drums that prepare the material first by mixing it with the iron powder and then, subjects it to magnetic separation on the electromagnetic drum, as shown in fig. 1.

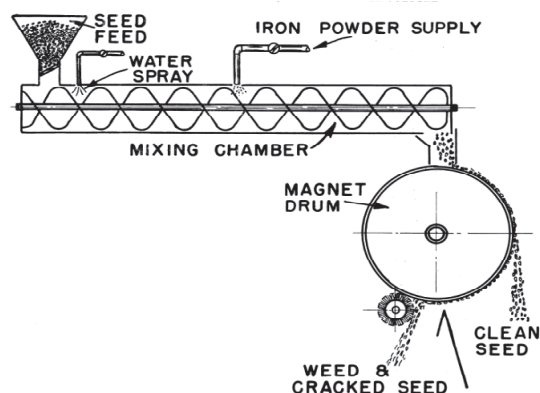


Figure 1 The scheme of a seed sorting/cleaning machine with drum on electromagnetic way [3]

In Romania, these machines have been introduced since the year 1924, and over the period 1938-1940 has spread on a national scale, [1].

At present the interest in the theoretical and experimental research of this category of machines, has increased, both in order to improve the work performance and also to obtain useful information in the design activity and efficient usage in various work conditions.

Thus, this paper has developed the mathematical model of movement of smooth seeds on the surface of the separator drum and also in the movement of free fall after detachment off the drum, taking in consideration the air resistance.

On this basis there have been performed the numerical simulation for different plausible values in practical situations of the parameters that influence movement of seeds, in order to understand and quantify their effect on the seeds smooth trajectory.

MATHEMATICAL MODELING

The Particle motion on the drum surface

At this point will analyze the smooth particles motion (with non-magnetic properties) on the electromagnetic drum surface (particle separator). The clover or alfalfa smooth seeds have relatively small dimensions and for this reason will be assimilate as material particles on which the friction force acts due to the contact of them and the cylindrical drum surface (with radius R).

Similar to the minerals particles, as it can be observed in Fig.2, the particle trajectory can be divided into three phases.

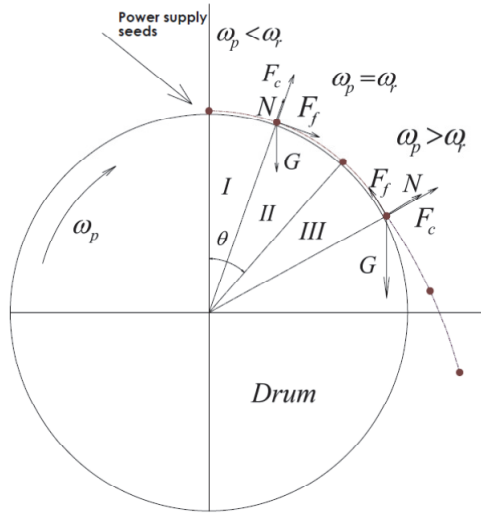


Figure 2 Particle force diagram during the motion on separator (magnetic) surface.

In phase I, the particle has an accelerated movement due to the friction force F_f and its weight tangential component ($G \sin \theta$).

The particle trajectory on these conditions can be described by the equations (1), (2), [2]:

$$\ddot{\theta} + \mu_d \dot{\theta}^2 = \frac{g}{R} (\sin \theta + \mu_d \cos \theta) \quad (1)$$

The solution of differential form of the eq. (1) is the eq. (2):

$$\dot{\theta}^2 = c \cdot e^{-2\mu_d\theta} + \frac{2\mu_d a + b}{1 + 4\mu_d^2} \sin\theta + \frac{2\mu_d b - a}{1 + 4\mu_d^2} \cos\theta \quad (2)$$

where:

$$a = \frac{2g}{R}; b = \frac{2\mu g}{R} \quad (3)$$

and μ_d is the friction dynamic coefficient, c is an integration constant that is defined by the initial conditions [2].

This phase ends when the particles speed ω_p comes to relative rest to the drum, that $\omega_p = \omega_r$, and starts the phase II.

In phase II, when $\omega_p = \omega_r$, it can be noticed the influence of static friction coefficient μ_s , ($\mu_s > \mu_d$) and ends when the friction force reverses, opposing particle slip, opposing to sliding of the particle before the drum. This phase can be defined by the next parameters:

$$\ddot{\theta} = 0 \text{ si } \dot{\theta} = \omega_r; \theta = \theta_{01} \quad (5)$$

and stops in the moment in which the friction force rich eq. (6).

$$F_f = \mu_s (G \cos\theta - mR\omega_r^2) = G \sin\theta \quad (6)$$

In the phase III the friction force components are smaller than the tangential component of the weight $G \sin\theta$, presented in eq. (7).

$$F_f = \mu_d (G \cos\theta - mR\dot{\theta}^2) < G \sin\theta \quad (7)$$

The particle motion in phase III is accelerated and slips on the drum surface in front of its movement, when $\omega_p > \omega_r$, and stops when the particle detaches on the drum, moving in free flight.

The particle trajectory in third phase it can be obtained from eq. (1) and (2) replacing μ_d with $(-\mu_d)$, and obtaining eq. (8):

$$\ddot{\theta} - \mu_d \dot{\theta}^2 = \frac{g}{R} (\sin\theta - \mu_d \cos\theta) \quad (8)$$

The solution of eq. (8) is presented as eq. (9):

$$\dot{\theta}^2 = c \cdot e^{2\mu_d \theta} - \frac{2\mu_d a + b}{1 + 4\mu_d^2} \sin \theta - \frac{2\mu_d b - a}{1 + 4\mu_d^2} \cos \theta \quad (9)$$

The initial conditions for this equations are:

$$\begin{aligned} \theta &= \theta_{02} \\ \mu_d (G \cos \theta_{02} - m R \dot{\theta}_{02}^2) &= G \sin \theta_{02} \\ N = G \cos \theta_{02} - m R \dot{\theta}_{02}^2 &> 0 \end{aligned} \quad (10)$$

The particle detachment from the drum surface occurs when θ_{03} moment in which $N = 0$, namely:

$$G \cos \theta_{03} - m R \dot{\theta}_{03}^2 = 0 \quad (11)$$

This angle θ_{03} represent the end of phase III., when it exists.

Depending on parameters μ , R , ω_r and the seed supply system used on the drum it can be notice the next situations during the separation process: only phase I; phase I and II; phase I, II and III.

Those situations will be analyzed in detail applying the numerical model in the next section.

The particle movement after drum detachment.

After the smooth seed detach from the drum there have a free flight, similar to throw particles with an initial speed and a specific angle from horizontal. The particle trajectory, neglecting the air resistance, is presented in eq. (12). [2]

$$y = x \tan \theta_1 + \frac{g(1 + \tan^2 \theta_1)}{2v_{s1}^2} \cdot x^2 \quad (12)$$

Using the above equation it can be established the position of the collecting ducts during the seeds free flight, fig. 3.

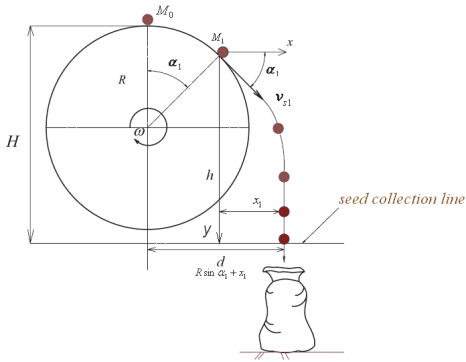


Figure 3 The trajectory of the particle in free fall without air resistance [2]

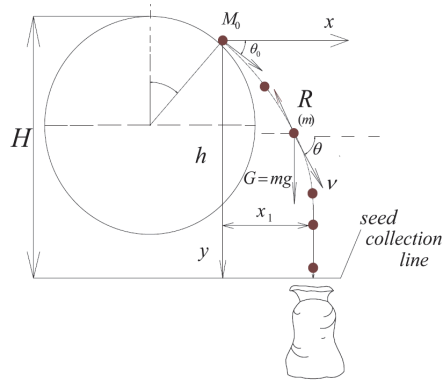


Figure 4 The trajectory of the particle in free fall considering air resistance

Now will analyze the particle movement, taking into consideration the air resistance, case that is presented in fig.4.

Considering that the particle with mass m , with a free motion at a speed v . The air resistance R has an opposite direction to the speed and is given by Newton's famous eq. (13). [4, 5]

$$R = c\rho_a S \frac{v^2}{2} \quad (13)$$

where: c – is the dimensionless coefficient representing the seed aero dynamical resistance; ρ_a – is the air density; S – is the particle frontal surface, v – is the particle speed.

At present, most often, is used in the expression of R , coefficient of resistance k with the size (m^{-1}) defined by eq. (14), [5].

$$k = c\rho_a \frac{S}{2m} \quad (14)$$

This coefficient is obtained from $\frac{R}{m} = kv^2$.

The connection between the resistance coefficient k with particle flowing speed, denoted in the flowing state into a vertical air flow of speed u ($=u_p$), we have:

$$R = c\rho_a S \frac{u_p^2}{2} = mg, \text{ where } ku_p^2 = g.$$

Therefore:

$$k = \frac{g}{u_p^2} \quad (15)$$

Reported to a rectangular fix system with origin in the detachment point (fig.4), the trajectory equations during the particle free flight is presented as eq. (16) ,[2, 4, 8]:

$$\begin{cases} \ddot{x} = -kv^2 \cos \theta \\ \ddot{y} = g - kv^2 \sin \theta \end{cases} \quad (16)$$

Knowing that $\dot{x} = v_x$ and changing the time variable t in θ , from the first eq. (16) it is obtained the eq. (17):

$$\frac{dv_x}{d\theta} \cdot \frac{d\theta}{dt} = -kv^2 \cos \theta \quad (17)$$

Taking in to consideration that $vdt = r d\theta$ (where r – the trajectory curvature radius from the that point) and $\frac{v^2}{r} = g \cos \theta$ (from the motion equation in Frenet coordinate) and $v_x = v \cos \theta$, after entering in eq. (17) and performing calculations, it obtain a differential equation with separable variables:

$$\frac{dv_x}{v_x^3} = -\frac{k}{g} \cdot \frac{d\theta}{\cos^3 \theta} \quad (18)$$

Having regard that: $\int \frac{dv_x}{v_x^3} = -\frac{1}{2v_x^2}$ and $\int \frac{d\theta}{\cos^3 \theta} = \frac{1}{2} \left[\frac{\sin \theta}{\cos^2 \theta} + \ln \operatorname{tg} \left(\frac{\theta}{2} + \frac{\pi}{4} \right) \right]$ after integration eq. (18) , for the left member within the limits of v_{x0} at v_x and the right member within the limits of θ_0 at θ and performing calculations, it's found:

$$v_x = \frac{1}{\sqrt{\frac{k}{g} \left[\frac{\sin \theta}{\cos^2 \theta} + \ln \operatorname{tg} \left(\frac{\theta}{2} + \frac{\pi}{4} \right) \right] - c^*}} \quad (19)$$

where $c^* = \frac{k}{g} \left[\frac{\sin \theta_0}{\cos^2 \theta_0} + \ln \operatorname{tg} \left(\frac{\theta_0}{2} + \frac{\pi}{4} \right) \right] - \frac{1}{v_0^2 \cos^2 \theta_0}$.

The eq. (19) allow to estimate the x and y coordinates of point placement on the trajectory. In this way, it can successively write: $v_x = \frac{dx}{dt} = \frac{dx}{d\theta} \cdot \frac{d\theta}{dt} = \frac{dx}{d\theta} \cdot \frac{g \cos \theta}{v} = v \cos \theta$.

From this it is obtained the eq. (20):

$$\frac{dx}{d\theta} = \frac{v^2}{g} = \frac{v_x^2}{g \cos^2 \theta} \quad (20)$$

Given the eq. (19) and eq. (20), results the eq. (21):

$$x = \int_{\theta_0}^{\theta} \frac{d\theta}{g \cos^2 \theta \left\{ \frac{k}{g} \left[\frac{\sin \theta}{\cos^2 \theta} + \ln \operatorname{tg} \left(\frac{\theta}{2} + \frac{\pi}{4} \right) \right] - c^* \right\}} \quad (21)$$

In this manner there, given that $v_y = v_x \operatorname{tg} \theta$, results eq. (22):

$$\frac{dy}{d\theta} = \frac{v_x^2}{g} \cdot \frac{\operatorname{tg} \theta}{\cos^2 \theta} \quad (22)$$

After the integration of eq. (22) was found the mathematical expression of y ordinate of the point, as in eq.(23).

$$y = \int_{\theta_0}^{\theta} \frac{v_x^2}{g} \cdot \frac{\operatorname{tg} \theta}{\cos^2 \theta} d\theta = \int_{\theta_0}^{\theta} \frac{\operatorname{tg} \theta \cdot d\theta}{g \cos^2 \theta \left\{ \frac{k}{g} \left[\frac{\sin \theta}{\cos^2 \theta} + \ln \operatorname{tg} \left(\frac{\theta}{2} + \frac{\pi}{4} \right) \right] - c^* \right\}} \quad (23)$$

The numerical integration of eq. (21) and (23) will generate the point trajectory in free flay taking in to consideration the air resistance, in the parametric coordinate $x = x(\theta)$ and $y = y(\theta)$.

The constructive conditions require that: $y = h$ (fig. 3) and from eq. (23) results the θ suitable. Form eq. (21), it is obtained the x coordinate, the collector position, as in fig.4. For θ_0 are taking the values obtained from the particle motion on the drum surface of the corresponding to the spindle separation position, and particle spindle speed is $v_0 = R \dot{\theta}_1$.

From eq. (15), results:

$$\frac{k}{g} = \frac{1}{u_p^2} \quad (24)$$

For alfalfa and clover seed, floating rate is in most cases register $u_p = 4 \dots 6,5 \text{ m/s}$, [3], which leads to $\frac{k}{g} = \frac{1}{42} \dots \frac{1}{16} = \dots$, values that will be used in the numeric mathematic model in eq. (21) and (23).

RESULTS

Study cases. Numerical applications

In this mathematical model will be consider the proper numerical values from the usual values field for three drums used at three operational electromagnetic separation machines of on way existing in work, presented in Table 1.

Table 1 Drum diameter values and rotation speed from three electromagnetic separation machines

Machine type	Drum diameter $\varnothing(\text{mm})$	Drum rotational speed (rot/min)
MD 400	$\varnothing 410$	53
EMS - 1	$\varnothing 468$	53
GOMPPER	$\varnothing 610$	50

In analyzes carried out we considered three values of the friction coefficient, in the field 0.25.....0.315 namely: $\mu = 0.25, 0.29, 0.315$.

Using the MathCAD numeric simulation program, were evaluated the positions θ_0 at detachment, the speeds $v_0 = R\dot{\theta}_1$, for all variations obtained for the three dimensions considered of the diameters of the drums and the three values of the friction coefficients.[2]

In the table 2 are presented the values of the seeds positions and speeds at the time of detachment off drum depending on the friction coefficient, for the three dimensions of the drum.

Table 2 Values of positions and speeds of seeds at detachment off drum

Nr. crt	μ	D 410 $\omega = 5.44$			D 468 $\omega = 5.23$			D 610 $\omega = 5.23$		
		$\dot{\theta}_1$ rad/s	θ_0 grade	v_0 m/s	$\dot{\theta}_1$ rad/s	θ_0 grade	v_0 m/s	$\dot{\theta}_1$ rad/s	θ_0 grade	v_0 m/s
1	0.25	5.95	51.76	1.219	5.57	49.16	1.303	4.88	42.29	1.488
2	0.29	5.99	51.76	1.228	5.6	49.16	1.31	4.91	41.521	1.498
3	0.315	6.01	51.76	1.232	5.62	49.16	1.315	4.924	41.059	1.502

It is found that, the particle speed register a slightly rise with the incensement of friction coefficient at the same drum diameter and a significantly incensement when the drum diameter was raised and the friction coefficient was maintained constant.

Also, from this results was noted that the drums with diameters of 410 and 468 mm, the particle detachment speed is greater than of drum ($\dot{\theta}_1 = \omega_p > \omega_r$), (v. tab.2), situation which

cannot take place from the physical point of view, because, sooner the when the particle entered at relatively rest, after which the displacement continues normally with drum speed, when $F_f > G \sin \theta$.

In the case of the drum with diameter of 610 (mm) it was noticed that particle speed is smaller than that of drum, ($\omega_p < \omega_r$), in all cases considered, which shows that the particle does not enter rest relatively, meaning that it is valid for the estimations made on eq. (2), for which the initial conditions were: $t = 0$, $\theta = 0$ and $\dot{\theta} = 0$. Obtaining the integration constant $c = \frac{a - 2\mu_d b}{1 + 4\mu_d^2}$, which was substituted in eq. (2), was used in calculations from phase I.

Thus, for the drums with diameters of D410 and D 468, is recommended to increase the rotation speed of work for each friction coefficient in part, in order to enter the relatively repose in detachment moment (when $\dot{\theta}_1$ is really ω_r).

Starting from the particle detachment position, when it is at relative rest $\cos \alpha^* = \frac{R\omega_r^2}{g}$ and

$\theta^* > \theta$ it detaches in the moment when $\omega_r = \dot{\theta}_1$ ($n^* = \frac{30 \cdot \omega_r}{\pi}$).

The data corresponding to the situation are presented in tab.3.

Table 3 The corrected values for rotation speeds of the drums and speeds at detachment of the particle

D mm	ω_r rad/s	$\mu = 0.25$		$\mu = 0.29$		$\mu = 0.315$	
		θ (°)	n rpm	θ (°)	n rpm	θ (°)	n rpm
410	5.44	51.76*	56.8*	-	57.2*	51.76*	57.4*
468	5.23	49.16*	53.2*	-	53.5*	49.16*	53.7*
610	5.23	42.29	50	41.521	50	41.059	50

(*) The corrected values

The seed trajectory in free fall

Using the MathCAD program, it was numerical integration the eq. (21) and (23), and was obtained the particle trajectory in free fall taking into account the air resistance.

For exemplification, for the same friction coefficient $\mu = 0.25$, were traced the seed trajectories when is taken in to consideration the air resistance for those three machines that have the drum diameters of D 410 (mm), D 468 (mm) and D 610 (mm), presented in the graphic from fig. 5.

For the same diameter D 610 (mm), the seed trajectory was drawn taking into account the air resistance for those three coefficients $\mu = 0.25, 0.29, 0.315$, shown in fig. 6, from this

graphic it was observed that the trajectory hasn't a significant deviation, because the seed detachment place and speeds not differ significantly.

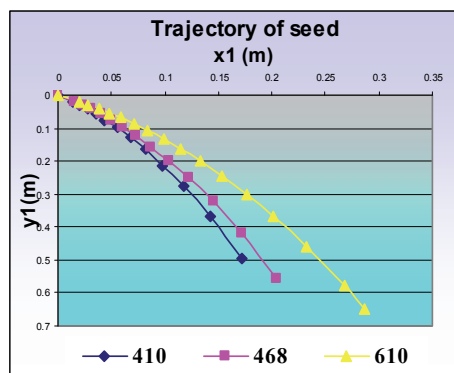


Figure 5 Trajectory of the seed for the same friction coefficient, $\mu = 0.25$, for the three drums

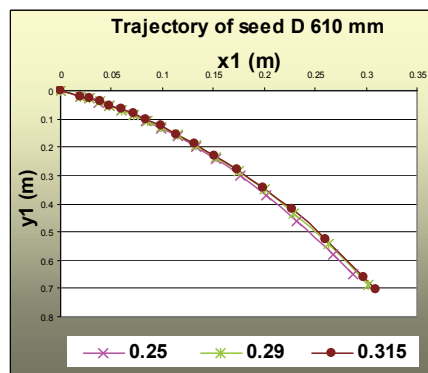


Figure 6 Trajectory of the seed for the three friction coefficients, for the same diameter

In the fig. 7 - 9, was made a comparative study for the three different drum diameters, in which were presented the trajectory in free flight of smooth seeds neglecting the air resistance and the trajectory taking into account air resistance for the same friction coefficient ($\mu = 0.25$).

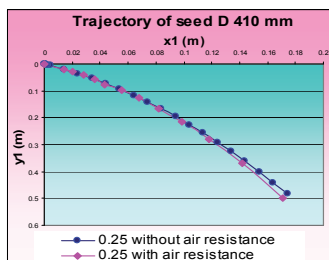


Figure 7 Trajectories of the seed for D410 (mm)

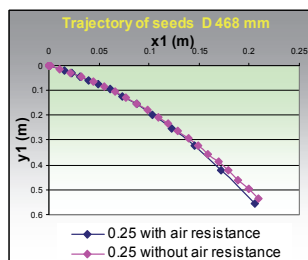


Figure 8 Trajectories of the seed for D468 (mm)

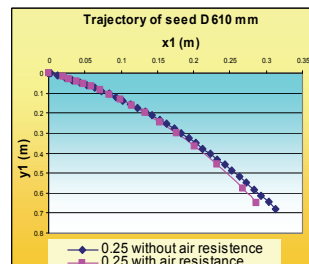


Figure 9 Trajectories of the seed for D610 (mm)

From graphical representations it can be observed a slightly significant difference between the trajectories in free flight of the seeds, air resistance influencing insignificantly the trajectory of the seed, for height of fall of 0.5-0.7 m, commonly found at the existing machines into production.

Results from here, the fact that it can be used with good results the eq. (12) to trace the trajectory of seed in free flight corresponding of neglecting air resistance, an equation much more simple and convenient of applied compared with eq. (21) and eq. (23), that have a much more incommode expression to calculate the air resistance.

CONCLUSIONS

In the present paper were developed mathematical models for smooth particle motion on cylindrical drum that have a rotational motion during the electromagnetic separation process (eq. (2) and (9)) and of trajectory in free fall with the neglect of air resistance (eq.(12)) and with consideration of air resistance (eq. (21) and (23)).

Also, was performed the numerical simulation of the smooth particle motion on the drum and free fall for three drum diameter values, for three different values of friction coefficients and different rotation speeds of the drums.

From the numerical simulation was noted an significant deviation of the smooth particle trajectory on or without air resistance, for heights of 0.5 and 0.7 (m), which can conduct to good results when it is used to trace the particle trajectory without air resistance, that has a simple form and easy to use, eq.12.

It highlighted the practical utility of the mathematical models developed in the design activity and use by specialists of these categories of machines.

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THE INTENSIFICATION OF SHAKING PROCESS ON THE CONVENTIONAL COMBINE HARVESTERS

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SUMMARY:

The conventional cereal harvester combines have in composition a working organ named straw walker which separate the seeds out of straws coming from the tangential threshing device. The working capacities of the straw walker, and implicitly of harvester combine, depend on the characteristics of straw walker (design and kinematic regime). The purpose of the theoretical study is to determine the characteristics of straw walker for the intensification the shaking process, based on a mathematical model of straw displacement on straw walker. The study of intensification of shaking process to the conventional cereal harvesting combines is based on the hypothesis that the intensity of seeds separation from the straw placed on a straw walker is directly proportional to the total duration of all straw jumps on the walkers. The experimental results made demonstrated the importance greater of the step wall angle in relation to the vertical of the grid compared with the increase of rotation speed and crankpins crankshaft radius of the straw walker.

Key words: cereal harvesting combine, straw walker, straw displacement.

INTRODUCTION

The straw walker is one of the main working organs of a conventional cereal harvesting combine. It is positioned in the technological flow of these combine between the tangential threshing device and the cleaning system (Fig.1).

Vegetal mass arrived on straw walker (Fig.2) from the threshing device, is a mixture of long straw, short straw, hulls and seeds. This mixture it is subject to periodic shaking to release separation of seeds from straw, directing them to the cleaning system and removal of straw from the combine with as small losses in grains.

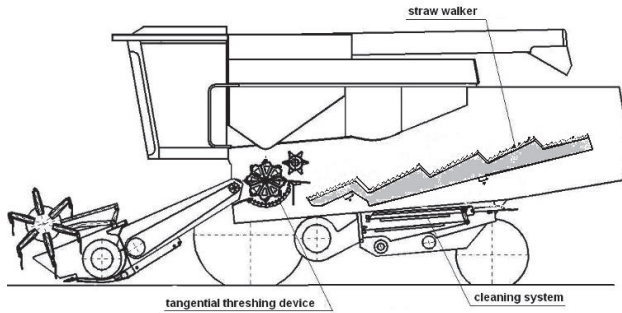


Fig. 1 The main working organs of a conventional cereal combine [6]

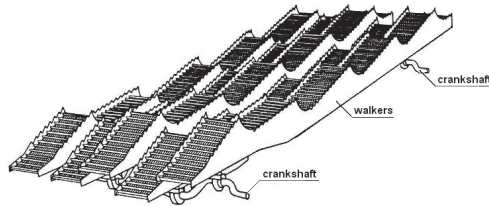


Fig. 2 Straw walker [1]

To current conventional harvesting combines, the straw walker consists of 4...8 walkers and two crankshafts, in which the back is for power of straw walker. The walkers (Fig.3) are made from metal, a length of 3.3...4.6 m, width of an item being 0.21...0.28 m, have in composition a number of steps and grids for seeds separation and are usually, in trough cross-section in form of gutter. The gutter has side walls with jagged edges for retaining and advancing of the straw on the walkers. If the walkers are not provided with gutter, under them is an inclined plane for directing the components separated through grids to the cleaning system. The walkers have a plane-parallel motion, any point in doing circles of radius equal to the crankpin radius of straw walker crankshafts and comprises three functional zones: feeding, separation and exhausting. On all functional zones is carrying out the separation of seeds from straw, but the separation zone has the optimal constructive characteristics necessary for separation.

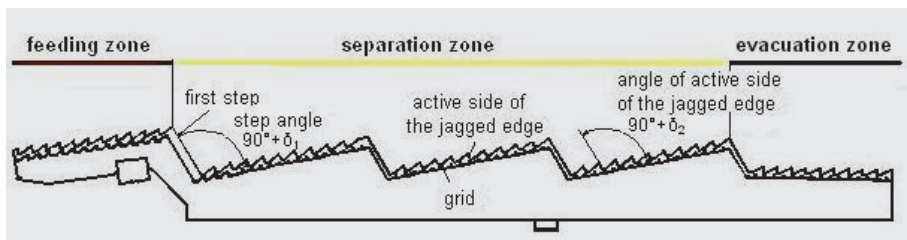


Fig. 3 Representation of functional zones of a walker [6]

The straw walkers of current conventional harvester combines are independent walkers, which walker are extended circular some over others with different angles, each walker acting only on the straw found above him. These straw walkers are indicated in the case of short straws, result from the threshing device with multiple rotors of current harvester combines.

The crankpins radius of the crankshaft is 40...75 mm and the rotation speed of the straw walker is comprised within the limits 150...270 rot/min. The crankshaft crankpins of the straw walker with four walkers are arranged two by two at 180° , according to Figure 4.

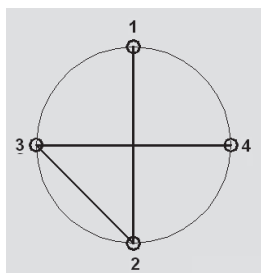


Fig. 4 The crankshaft crankpins positions of the straw walker with four walkers [3]

METHODS

We present below the kinematic study of the straw displacement on straw walker of conventional harvesting combines for a generic angle $90^\circ + \delta$, between the wall of steps or active side of the jagged edges and the appropriate grids [6].

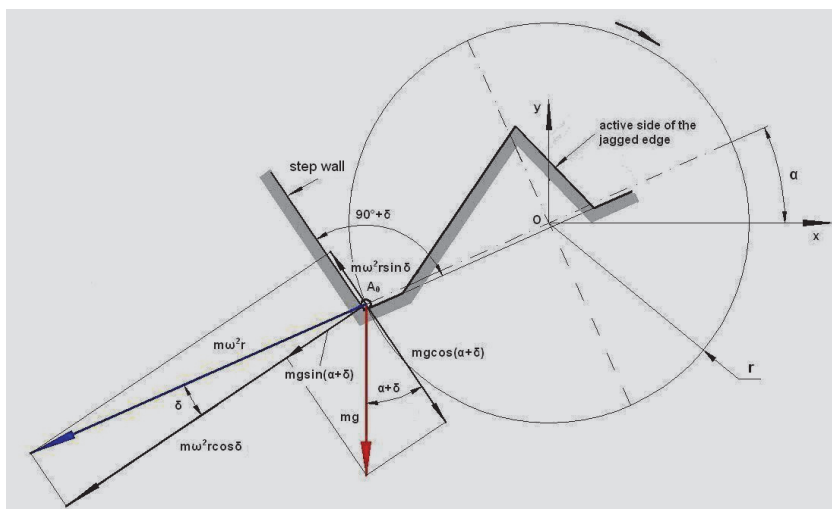


Fig. 5 Diagram of forces acting on a particle of straw located on the walker, found in the point A_0

The diagram of forces acting on a particle of straw driven by wall of step and by the active side of jagged edges of the walker, found in the point A_0 , is shown in Figure 5.

Within the range $[A_0 A_1]$, the straw located on the grid is compressed by the walker which is rising.

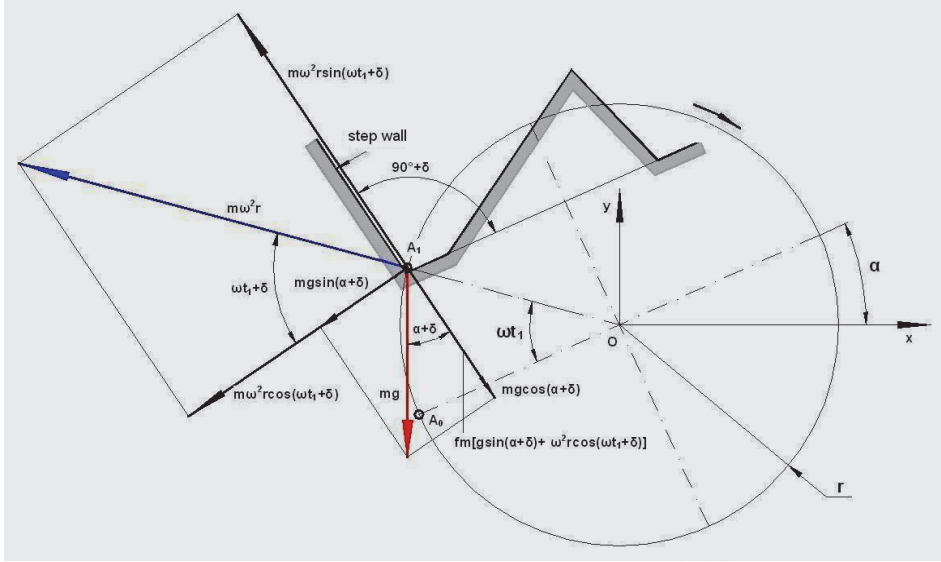


Fig. 6 Diagram of forces acting on a particle of straw located on the walker, found in the point A_1 [6]

To find the angle of detachment of the straw from the grid ωt_1 , place the equilibrium condition of forces acting on the straw particle in the point A_1 :

$$m\omega^2 r \sin(\omega t_1 + \delta) = mg \cos(\alpha + \delta) + fm [g \sin(\alpha + \delta) + \omega^2 r \cos(\omega t_1 + \delta)] \quad (1)$$

Results the value of the detachment angle of straw particle from the grid ωt_1 :

$$\omega t_1(k, \alpha, \delta, f) = \arccos \frac{\sqrt{k^2(1+f^2) - [\cos(\alpha + \delta) + f \sin(\alpha + \delta)]^2} - f[\cos(\alpha + \delta) + \sin(\alpha + \delta)]}{k(1+f^2)} - \delta \quad (2)$$

where:

ωt_1 is the detachment angle of the straw particle from the grid;

m – mass of a straw particle;

ω – angular speed of the walker;

r – the crankpins crankshaft radius of the straw walker;

α – inclination of the separation grid to the horizontal;

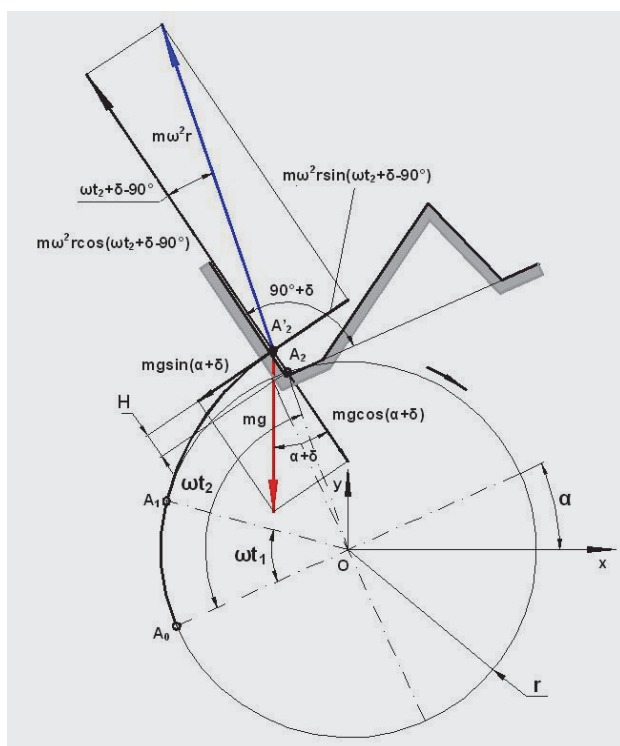


Fig. 7 Diagram of forces acting on a particle of straw located on the walker, in the point A_2 [1,6]

To find the angle at which begins the jump of straw ω_{t_2} , place the equilibrium condition of forces acting on the straw particle in the point A':

$$m\omega^2 r \sin(\omega t_2 + \delta - 90^\circ) = mg \sin(\alpha + \delta) \quad (3)$$

where:

ωt_2 is the angle at which begins the jump of straw.

Result:

$$\omega t_2(k, \alpha, \delta) = \arcsin \frac{\sin(\alpha + \delta)}{k} + 90^\circ - \delta \quad (4)$$

Within the range $[A_1A_2]$, the straw slide along the wall of step and active part of the jagged edges. The movement straw speed along the wall of step of the walker is :

$$v_2 = c\omega r; \quad c = \cos(\omega t_1 + \delta) - \cos(\omega t_2 + \delta) + f[\sin(\omega t_1 + \delta) - \sin(\omega t_2 + \delta)] - \frac{\cos(\alpha + \delta) + f\sin(\alpha + \delta)}{k}(\omega t_2 - \omega t_1) \quad (5)$$

where:

v_2 is the movement straw speed along the wall of step and of the active part of jagged edges;

c - variation coefficient of straw speed.

The running space by the straw on the wall of step and on the active side of the jagged edges is:

$$H(k, \alpha, \delta, f, r) = \frac{cr}{2}(\omega t_2 - \omega t_1) \quad (6)$$

where:

H is the running space by the straw on the wall of step and on the active side of the jagged edges;

After the detachment of straw from the separation grids and its deplacement along the wall of step, the active side of the jagged edge and the thresholds of the grids, in the interval $[A_2A_3]$ occur the straw jump on the walker. During the jump, the aeration degree of the straw increases and the probability of separating the seeds from straw reaches maximum value.

In point A_2 the straw has the speed R , composed from the speed of walker V and the movement speed of straw on the wall of step v_2 :

$$\begin{aligned} \vec{R} &= \vec{V} + \vec{v}_2 \\ V &= \omega r \\ v_2 &= c\omega r \\ R &= \omega r \sqrt{1 + c^2 + 2ccos(\omega t_1 + \delta)} \end{aligned} \quad (7)$$

The speed of straw R decomposes after the cartesian axis system xoy. The displacement of a straw particle at a complete rotation of the walker is shown in Figure 8.

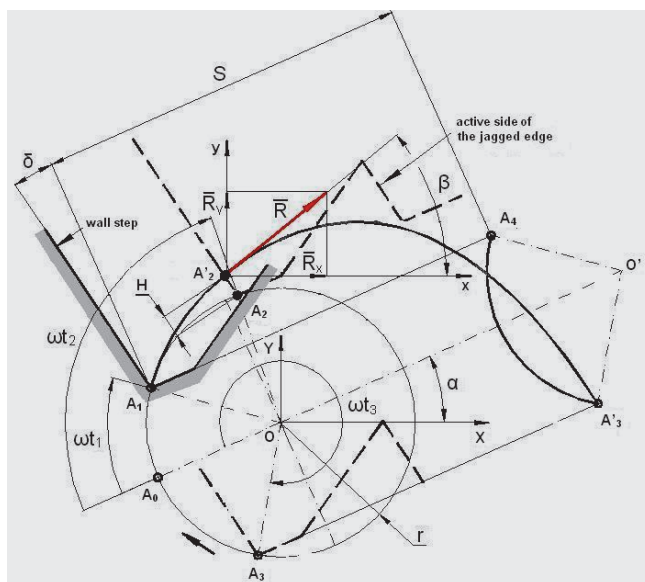


Fig.8 The displacement of a straw particle at a complete rotation of the walker

$$\begin{aligned}
 R_x &= R \cos \beta = \omega r \cos \beta \sqrt{1 + c^2 + 2c \cos(\omega t_2 + \delta)} \\
 R_y &= R \sin \beta = \omega r \sin \beta \sqrt{1 + c^2 + 2c \cos(\omega t_2 + \delta)} \\
 \beta &= \alpha + 90^\circ - \omega t_2 + \arcsin \frac{c \sin(\omega t_2 + \delta)}{\sqrt{1 + c^2 + 2c \cos(\omega t_2 + \delta)}}
 \end{aligned} \tag{8}$$

where

R_x and R_y are the speed straw projections R on the Cartesian axis system xoy ;

β – angle of the speed vector R in relation to the horizontal.

The walker found in point A_2 throws straw on a trajectory determined by the relations:

$$y = x \tan \beta - \frac{x^2}{2kr \left[1 + c^2 + 2c \cos(\omega t_2 + \delta) \right] \cos^2 \beta} \tag{9}$$

The straw particle falls upon the walker in point A_3 . The coordinates of this point are determined by the walker angle ωt_3 .

$$\begin{aligned}
 \omega t_3(k, \alpha, \delta, f) &= \omega t_2 + A + \sqrt{A^2 + B} \\
 A &= k \frac{\sin(\beta - \alpha)}{\cos \alpha} \sqrt{1 + c^2 + 2c \cos(\omega t_2 + \delta)} \\
 B &= \frac{ck \cos \delta}{\cos \alpha} (\omega t_2 - \omega t_1) - \frac{2k}{\cos \alpha} (\sin \omega t_3 - \sin \omega t_2)
 \end{aligned} \tag{10}$$

where

ωt_3 is the angle at which the straw particle falls on the walker after the jump.

The value of the duration of a straw jump on the walker at a complete rotation of it is given by the relation:

$$t_{\text{salt}} = \frac{\omega t_3 - \omega t_2}{\omega} = (\omega t_3 - \omega t_2) \sqrt{\frac{r}{k g}} \quad (11)$$

where:

t_{salt} is the duration of a straw jump on the walker at a complete rotation of it.

Using the expressions of functions ωt_2 and ωt_3 , result:

$$t_{\text{salt}}(k, \omega t_1, \alpha, \delta, f, r) = \left[\frac{\sin(\beta - \alpha)}{\cos \alpha} \sqrt{1 + c^2 + 2c \cos(\omega t_1 + \delta)} + \sqrt{\frac{\sin^2(\beta - \alpha)}{\cos^2 \alpha} [1 + c^2 + 2c \cos(\omega t_1 + \delta)] + \frac{c \cos \delta}{k \cos \alpha} (\omega t_1 - \omega t_1) - \frac{2(\sin \omega t_1 - \sin \omega t_1)}{k \cos \alpha}} \right] \sqrt{\frac{kr}{g}} \quad (12)$$

For the calculation on the straw displacement S on the separation zone of the walker at a full rotation of the straw walker shaft is used the relationship:

$$S(k, \omega t_1, \alpha, \delta, f, r) = \frac{r}{\cos \alpha} \left[(\omega t_1 - \omega t_1) \sqrt{1 + c^2 + 2c \cos(\omega t_1 + \delta)} \cos \beta + \cos(\omega t_1 - \alpha) - \cos(\omega t_1 - \alpha) - \frac{c}{2} (\omega t_1 - \omega t_1) \sin(\alpha + \delta) \right] \quad (13)$$

where:

S is the size of straw jump on the separation zone of the walker at a full rotation of the straw walker axle.

During the jump, the aeration degree of the straw increases and the probability of separating the seeds from straw is maximal. The theoretical study hypothesis is that the intensity of seeds separation from the straw placed on a straw walker is directly proportional to the total duration of all straw jumps on the walkers.

The total duration of straw jumps on one meter of the walker separation zone is calculated with the relation:

$$T_{\text{salt}}(k, \omega t_1, \alpha, \delta, f, r) = \frac{t_{\text{salt}}}{S} = \frac{\left[\frac{\sin(\beta - \alpha)}{\cos \alpha} \sqrt{1 + c^2 + 2c \cos(\omega t_1 + \delta)} + \sqrt{\frac{\sin^2(\beta - \alpha)}{\cos^2 \alpha} [1 + c^2 + 2c \cos(\omega t_1 + \delta)] + \frac{c \cos \delta}{k \cos \alpha} (\omega t_1 - \omega t_1) - \frac{2(\sin \omega t_1 - \sin \omega t_1)}{k \cos \alpha}} \right] \sqrt{\frac{kr}{g}}}{\frac{r}{\cos \alpha} \left[(\omega t_1 - \omega t_1) \sqrt{1 + c^2 + 2c \cos(\omega t_1 + \delta)} \cos \beta + \cos(\omega t_1 - \alpha) - \cos(\omega t_1 - \alpha) - \frac{c}{2} (\omega t_1 - \omega t_1) \sin(\alpha + \delta) \right]} \quad (14)$$

where

T_{jump} is the total duration of straw jumps along one meter of the walker separation zone.

Diagrams of partial functions $T_{\text{jump}}(k, \omega t_1, \alpha, \delta, f, r)$ are presented in Figure 9.

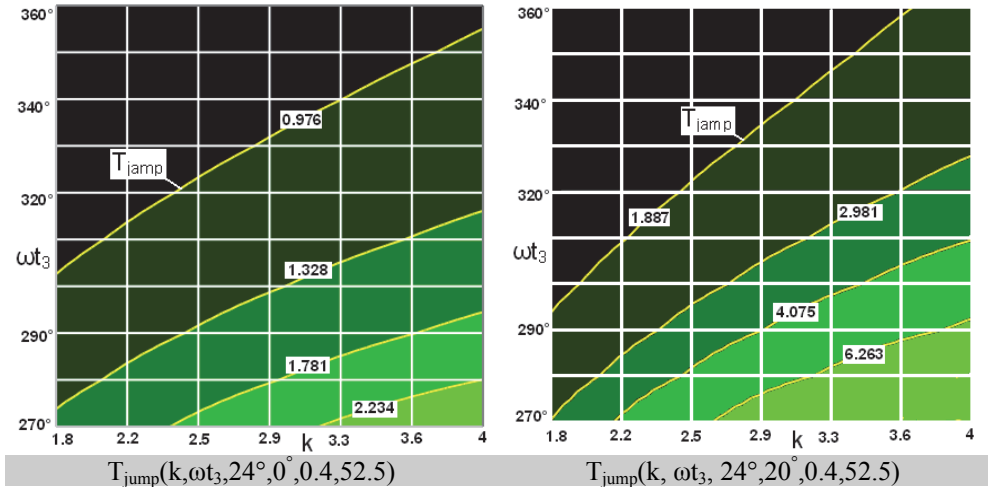


Fig. 9 Partial function diagrams $T_{jump}(k, \omega t_3, \alpha, \delta, f, r)$

To calculate the speed straw displacement on the walker using the relation:

$$v(k, \omega t_3, \alpha, \delta, f, r) = \frac{\sqrt{kgr}}{2\pi \cos \alpha} \left[(\omega t_3 - \omega t_1) \sqrt{1 + c^2 + 2c \cos(\omega t_3 + \delta) \cos \beta} + \cos(\omega t_3 - \alpha) - \cos(\omega t_3 - \alpha) - \frac{c}{2} (\omega t_3 - \omega t_1) \sin(\alpha + \delta) \right] \quad (15)$$

where

v is the speed straw displacement on the walker.

The straw has different thickness and aeration degrees depending on position of the walker. These decrease in direct proportion to the straw forward on walkers, due to strokes received from the walkers.

According to [7], the layer thickness of the straw from straw walker is given by relation:

$$H_{straw} = \frac{\lambda q}{b \gamma_v v} \quad (16)$$

where:

H_{straw} is the layer thickness of the straw;

λ – straw content coefficient in the total of harvested mass;

q – combine's feeding flow, in kg/s;

b – thrasher width, in m;

γ_v – volumic mass of straw, in kg/m³; The volumic mass of the straw depends on straw composition and humidity. At the current combines, due to increased fragmentation of straw, it has higher values. $\gamma_v = 15 \dots 25 \text{ kg/m}^3$ [7];

v – the displacement speed of straw on walkers, in m/s.

The height of the first step of the walker must be greater than or equal to the layer thickness of the straw located on the separating grid that follows to the step, so that it will be fully driven to evacuation [6].

$$H_{\text{step}} \geq H_{\text{straw}} \quad (17)$$

where:

H_{step} is the height of the first step;

H_{straw} - the layer thickness of the straw from the grid which follows to the first step.

For a block straw displacement on the separation zone of the walker, the following conditions must be met [6]:

- the walls of steps, the active side of jagged edge and of separation grid thresholds of the walker must have the same tilt angle δ against the to the vertical of the grids;
- the active side height of the jagged edge and thresholds of the separation grids must be equal to or greater than the displacement value H of the straw on these active sides (Figure 10).

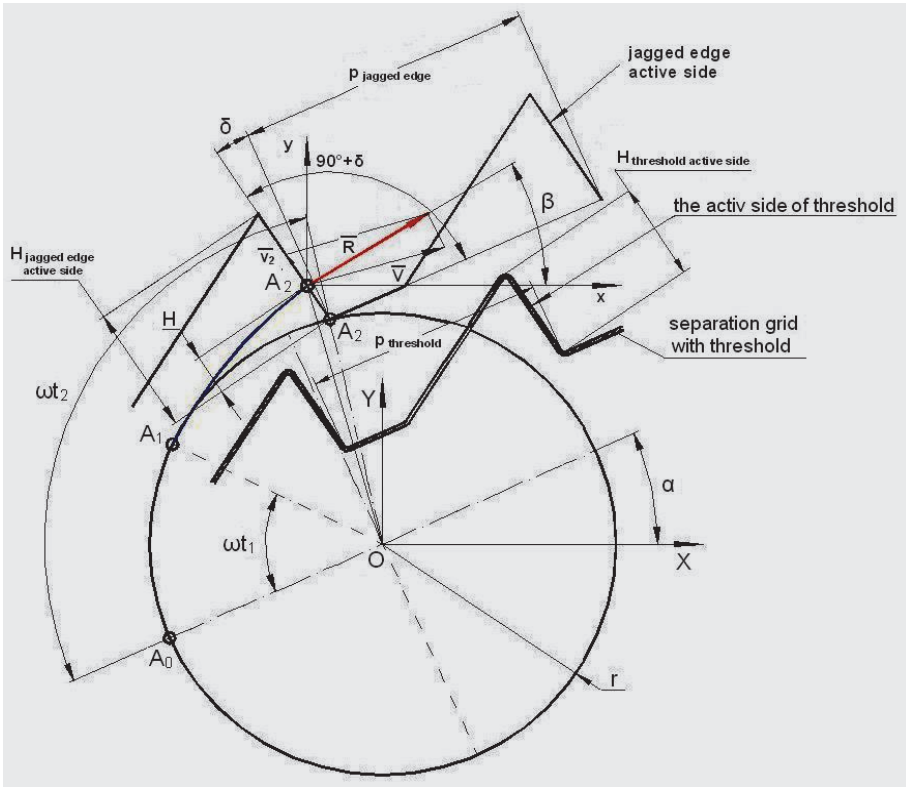


Fig. 10 The speed of straw particle when the jump is happening and constructive characteristics of the walker [6]

$$\begin{aligned} H_{\text{jagged edge active side}} &\geq H \\ H_{\text{threshold active side}} &\geq H \end{aligned} \quad (18)$$

where:

$H_{\text{jagged edge active side}}$ is the height of active side of the jagged edge;

$H_{\text{threshold active side}}$ - the height of the active side of the grids threshold;

H - the straw displacement on wall of step, on the active side of jagged edge and on grids thresholds, relation 6.

RESULTS

We present below an example for determining the main technical characteristics of a straw walker with four walker of Romanian harvesting combine C110.

For a straw walker with $\alpha=24^\circ$, $r=0.0525$ m and $f=0.4$, $b=1.08$ m, $\gamma v=25$ kg/m³, $\lambda=0.4$, result the values in Table 1.

Table 1 The main technical characteristics of a straw walker with four walker, for $\delta=0^\circ$ and $\delta=20^\circ$

k	δ	ωt_1	ωt_2	ωt_3	H[mm]	β	t_{jump} [s]	S [mm]	T_{jumps} [s]	v [m/s]	H_{straw} [mm]
1.8	0°	55.52°	103.06°	270°	5.14	24.59°	0.157	112	1.404	0.326	227
	20°	32.76°	92.70°	294°	5.66	46.80°	0.200	107	1.878	0.418	177

The main technical characteristics of a straw walker are for an angle of the wall step $\delta=20^\circ$ are much superior than for an angle of the wall step $\delta=0^\circ$, so:

- The total duration T_{jumps} of straw jumps along one meter of the walker separation zone and the speed v of straw displacement on the walker are higher with about 30%, while the layer thickness H_{straw} of the straw is lower with about 20%;
- The power consumption of the straw walker will be lower for the crankshaft crankpins positions of the straw walker with the angle of wall step $\delta=20^\circ$, according to Figure 11 (verification has not been done).

Table 2 Losses of seeds to Romanian harvesting combine C110 equipped with two straw walker, the first with $\delta=0^\circ$ and the second with $\delta=20^\circ$.

Index name	u.m.	Values				
the kinematics regime, k	-	2.06	2.14	2.37	2.69	2.82
losses from shaking process	%	0.57	0.52	0.55	0.57	0.64

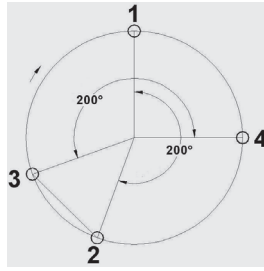


Fig. 11 The crankshaft cranks optimal positions of the straw walker with four walkers

We present below the experimental results from wheat harvesting with Romanian combine C110, equipped with two straw walker, the first with $\delta=0^\circ$ and the second with $\delta=20^\circ$ [5].

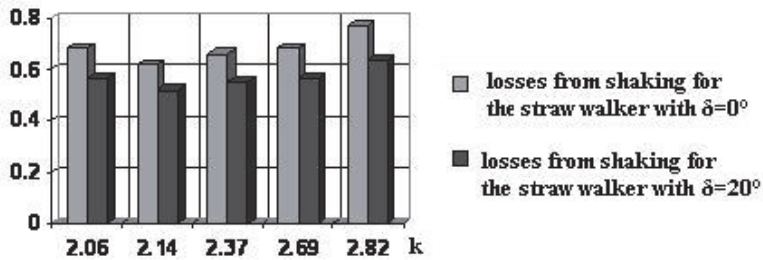


Fig. 12 Chart losses from shaking process to harvesting combine C110, equipped with two straw walkers, the first with $\delta=0^\circ$ and the second with $\delta=20^\circ$ [5]

CONCLUSION

1. Data presented in Table 1, Table 2 and Figure 12 demonstrate that for the intensification of shaking process to the conventional cereal harvesting combines it is indicated a careful study of the angle of step wall or active part of the jagged edges in relation to the vertical of the grid and it is not indicated to increase the rotation speed and the crankpins crankshaft radius of the straw walker, how does the most companies produce harvesting combines.
2. The study of intensification of shaking process to the conventional cereal harvesting combines provides to the designers of these combines the theoretical support for calculating the technical and functional characteristics of straw walker, which are necessary to reduce the power consumption and the losses from shaking process, increased the working capacity of straw walker and implicitly for the conventional cereal harvesting combines.
3. For various types of straw walkers of the harvesting combines in operation it is indicated the calculation of the optimal kinematic regime to intensify the shaking process.

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IMPROVING THRESHING SYSTEM FEEDING OF CONVENTIONAL COMBINE HARVESTERS

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SUMMARY

The working capacity of conventional cereal combine harvesters is mainly determined by the working capacity of tangential threshing system. This depends on the technical and functional characteristics of the threshing system itself, the characteristics of the harvested vegetal matter and the characteristics of the feeding threshing system with vegetal matter. The optimal feeding of the tangential threshing system with vegetal mass increases threshing capacity by entrainment a largest possible number of tranches of material brought by the conveyor with chains and slats of feeder house at a full rotation of the threshing cylinder. The study shows the conditions required to be met for improving threshing system feeding with vegetal matter to conventional cereal harvesting combines, the main condition being that the speed, number and distance between the slats of feeder house conveyor should be correlated with the cylinder bars number and speed of tangential threshing cylinder.

Key words: *cereal harvesting combine, feeder house conveyor, tangential threshing system,*

INTRODUCTION

The threshing system of the conventional cereal harvesting combines is type tangential. This is the main work organ in terms of the separation of the seeds and the energy consumption [1].

The tangential threshing system is positioned in the technological flow of a conventional cereal harvesting combine between the feederhouse and the straw walkers (Figure 1).

The main components of tangential threshing system with bars are: threshing cylinder with bars, concave, beater and concave extension [2] (Figure 2).

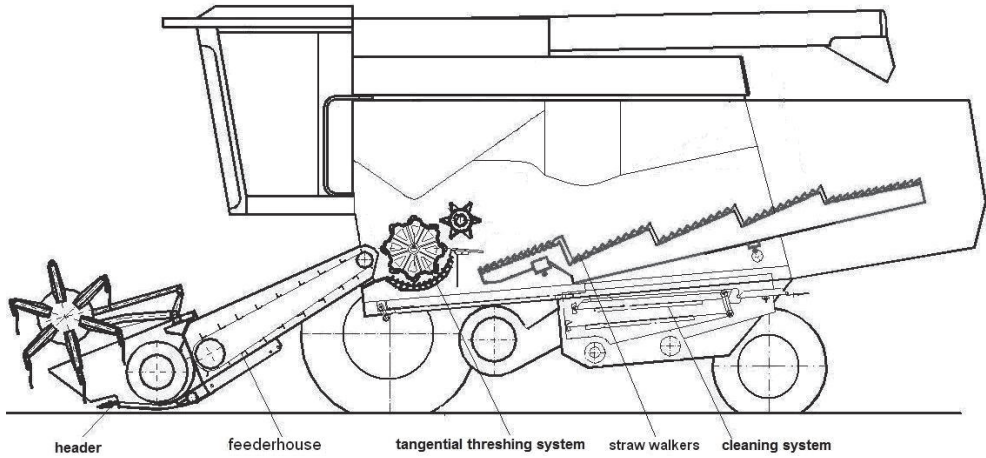


Fig. 1 The positioning of tangential threshing system in the technological flow of a conventional cereal harvesting combine [4]

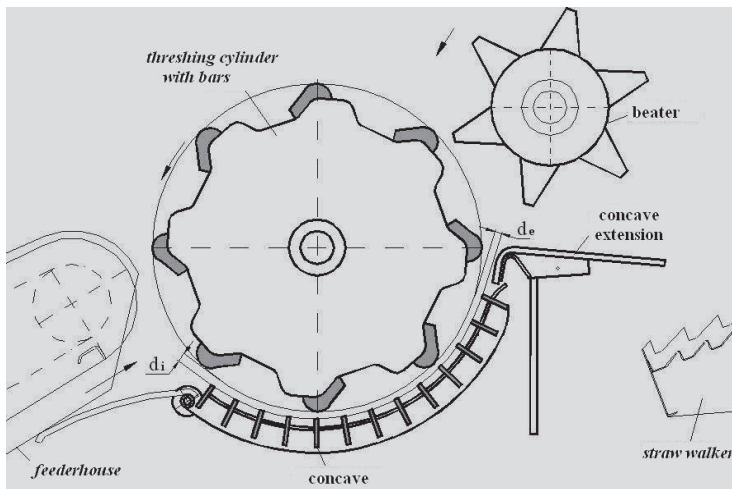


Fig. 2 The main components of tangential threshing system

In the tangential threshing system takes place threshing process, which consists in the separating the seeds from vegetal mass in the concave to the oscillating plane and cleaning system, and the straw go to the straw walkers [2].

The threshing cylinder is the component that transporting the vegetal mass in the threshing space between the cylinder and concave, to achieve the separation the seed from the rest of plants. The threshing cylinder with bars comprises a shaft, a number of molded or stamped rosettes, in which are screwed 6...10 bars, made of forged steel profile [3] (Figure 3).

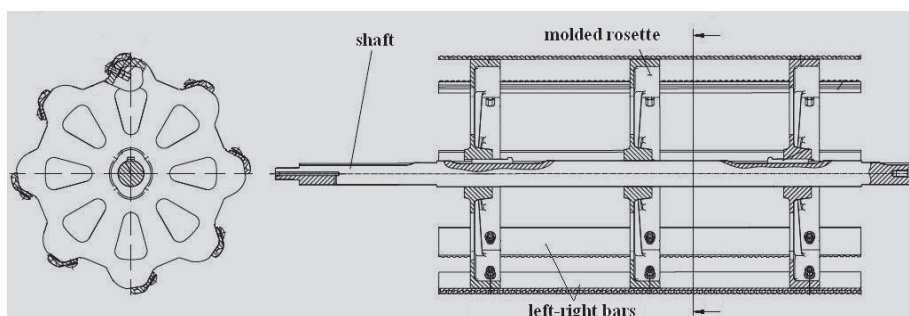


Fig. 3 The threshing cylinder with bars of Romanian cereal harveting combine C110

The bars of Romanian combine C110 are provided with a flat area and a dimpled area (Fig.4).

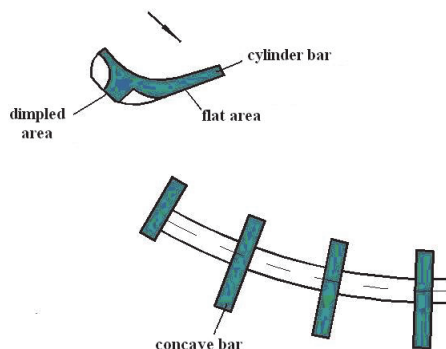


Fig. 4 Cylinder bar configuration of cereal harvesting combine C110 [4]

Flat area makes first contact with vegetal mass brought by the conveyor with chains and slats of feederhouse, providing its good taking and reducing the percentage of seeds damaged. Flat area produces a fan effect, an effect that increases speed of the vegetal mass who entry into the threshing space [3].

METHODS

Optimum feeding of the tangential threshing system with vegetal mass determines the increase of threshing capacity by entrainment a large number of tranches of material brought by conveyor chain and slats of feederhouse to a full rotation of the beater.

To achieve optimum feeding of the tangential threshing system with vegetal mass is necessary to meet the following conditions:

1. The tranche of vegetal mass (called short material) entrainment by one cylinder bar must be equal to the vegetal mass transported by one slat of the feeder house conveyor.

The first necessary condition is given by relation 1:

$$m_b = m_s \quad (1)$$

where

m_b is mass of material tranche entrainment by one cylinder bar;

m_s - the vegetal mass transported by one slat of feederhouse conveyor.

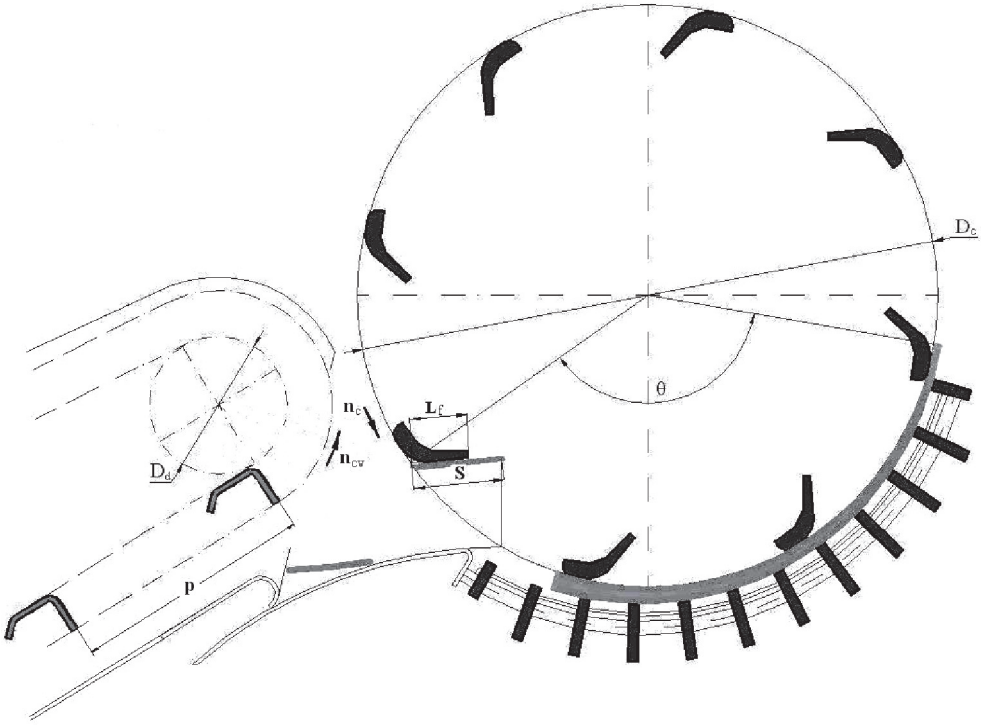


Fig. 5 The feeding area of tangential threshing system at the combine C110[4]

The harvested vegetal mass from the header of the conventional cereal harvesting combine is taken by a conveyor with chains and slats of feederhouse, ideally oriented with herringbones forward. Each slat is loaded with a quantity of material based on the vegetal mass flow supply of harvesting combine, chains speed and the distance between the conveyor chain slats. The vegetal mass transported by one slat is calculated with the relation 2 [4].

$$m_b = m_s = \frac{60qp}{\pi n_{cv} D_d} \quad (2)$$

where

m_b is the mass of material coached by one cylinder bar, in kg;

m_s – the mass of material transported by one slat, in kg;

q – vegetal mass flow of the harvesting combine, in kg/s;

p – the distance between the slats of conveyor, in m;

n_{cv} – chain gear wheel conveyor rotation speed, in rot^{-1} ;

D_d – chain gear wheel pitch diameter of conveyor, in m.

2. The time necessary for feeding of threshing system must be equal to the optimal time necessary for entrainment and transporting of material through the threshing space. The second necessary condition is given by relation 3 [4]:

$$t_{\text{feeding}} = t_{\text{op}} \quad (3)$$

where

t_{feeding} is time necessary for feeding of threshing system;

t_{op} – optimal time necessary for entrainment and transporting the material through the threshing space.

The time necessary for feeding of threshing system is calculated with the relation 4 [4]:

$$t_{\text{feeding}} = \frac{60p}{\pi n_{cv} D_d} \quad (4)$$

where

t_{feeding} is time necessary for feeding of threshing system, in seconds;

p – distance between the slats of conveyor, in m;

n_{cv} – chain gear wheel conveyor rotation speed, in rot^{-1} ;

D_d – chain gear wheel pitch diameter of conveyor, in m.

The optimal time necessary for entrainment and transporting the material through the threshing space is calculated with the relation 5 [4]:

$$t_{\text{op}} = \frac{30\theta}{\pi n_c} \quad (5)$$

where

t_{op} is optimal time necessary for entrainment and transporting the material through the threshing space, in seconds;

θ – angle maid by successive cylinder bars which entrainment and transporting the material through the threshing space, in radians;

n_c – cylinder rotation speed, in min^{-1} .

Resulting condition threshing process optimization: chain gear wheel conveyor rotation speed should be directly proportional to the speed corresponding cylinder rotation speed and it is calculated with the relation 6 [4].

$$n_{cv} = \frac{2p}{\theta D_d} n_c \quad (6)$$

where

n_{cv} is chain gear wheel conveyor rotation speed, in rot^{-1} ;

p – the distance between the slats of conveyor, in m;

θ - angle made by successive cylinder bars which entrainment and transporting the material through the threshing space, in radians;

D_d – chain gear wheel pitch diameter of conveyor, in m;

n_c – cylinder rotation speed, in min^{-1} .

3. The distance traveled by the material brought by feederhouse conveyor of during optimal time of cylinder bar must be greater than the flat area width of cylinder bar (Figure 6).

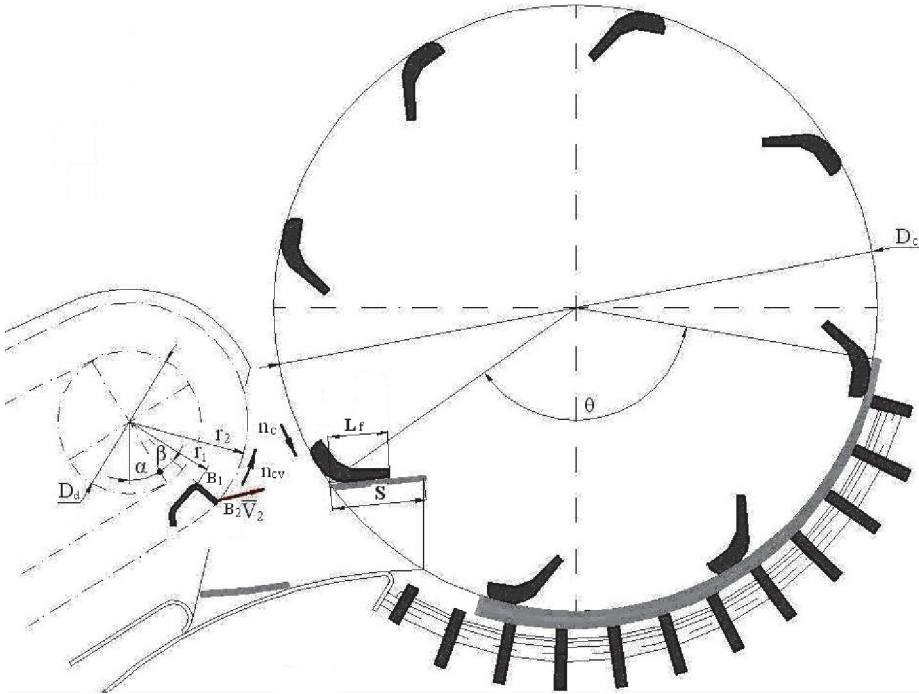


Fig. 6 The distance traveled by the material brought by feederhouse conveyor and the flat area width of cylinder bar [4]

$$S > L_f \quad (7)$$

where

S is distance traveled by material tranche brought by the conveyor during optimal time necessary for entrainment material, in m;

L_f - flat area width of cylinder bar, in m.

The distance traveled by material tranche brought by the conveyor during optimal time necessary for coach is calculate with the relation 7 [4].

$$S = \frac{15\theta}{\pi n_c} \sqrt{\left(\frac{\pi n_c}{30}\right)^2 (2r_2^2 - r_1^2) + g(r_2 - r_1) [\cos(\alpha + \beta) + \cos\alpha - f\sin(\alpha + \beta) - f\sin\alpha]} \quad (8)$$

where

S is distance traveled by material tranche brought by the conveyor during optimal time necessary for entrainment material, in m;

θ – angle maid by successive cylinder bars which entrainment and transporting the material through the threshing space, in radians;

n_c – cylinder rotation speed, in min^{-1} ;

n_{cv} – chain gear wheel conveyor rotation speed, in rot^{-1} ;

r_1 – arrangement radius of the material particle, which is in position B_1 , in m;

r_2 – arrangement radius of the material particle, which is in position B_2 , in m;

α – angle of inclination of the lower branch of the conveyor in relation to the horizontal, in degrees;

β – slat discharge angle of rotation moving, in rad.

4. The arc length of the cylinder circumference corresponding of the arc made by a number of consecutive cylinder bars which entrainment the material and transporting it into the threshing space must be correlated with the length of harvested plants (Figure 7).

The last condition threshing process optimization is expressed by the relation 9:

$$L_{\text{plant}} \leq R_c \left(\theta - \frac{2\pi}{z} \right) \quad (9)$$

where

L_{plant} is plants harvest length, in m;

R_c – cylinder radius, in m;

θ - angle maid by successive cylinder bars which entrainment and transporting the material through the threshing space, in radians;

z - number of bars of the threshing cylinder.

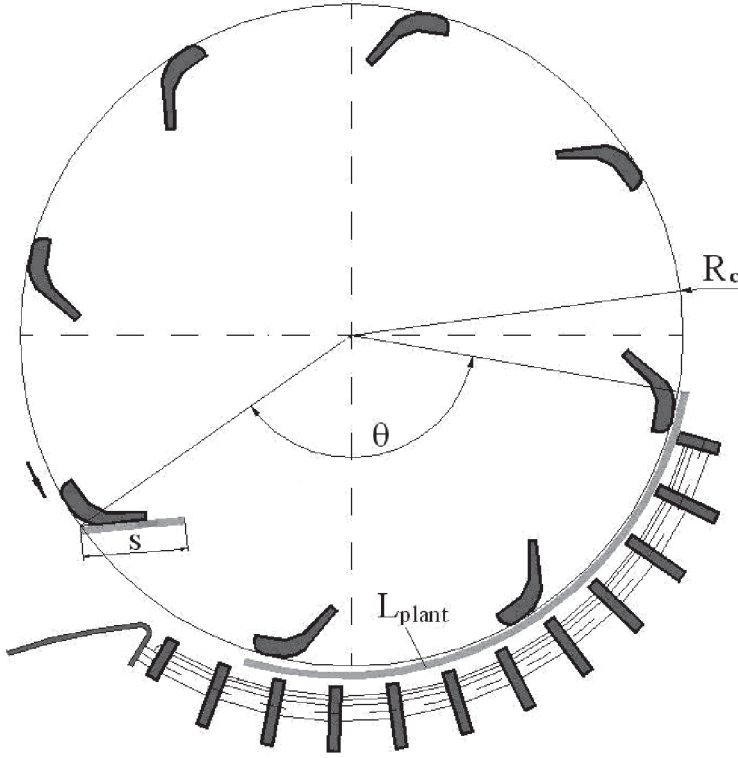


Fig.7 Length harvested plants entrainment and transporting into the threshing space

If all conditions are met of the threshing process optimization, we can calculate its maximum capacity threshing, according to the relation 10:

$$q_{\max} = \frac{\pi}{30\theta} n_c m_s \quad (10)$$

where

$q_{\max}$ is maximum capacity to the tangential threshing systems;

θ - angle made by successive cylinder bars which entrainment and transporting the material through the threshing space, in radians;

n_c – cylinder rotation speed, in min^{-1} ;

m_s – the mass of material transported by one slat, in kg;

We present below the diagram of working capacity variation for C110 threshing system depending on angle θ and mass of material transported by one slat m_s (Figure 8).

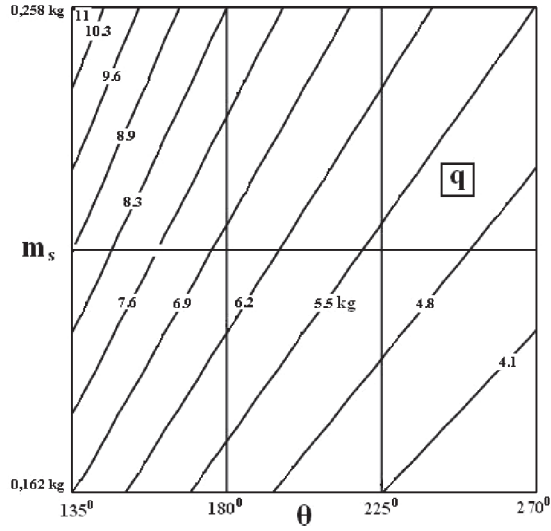


Fig. 8 Diagram of capacity working variation for C110 threshing system

Starting from the the diagram shown in Figure 7, the slope of increasing work capacity threshing system is higher for angle variation θ .

RESULTS

We present below the results calculated according to the study presented of feeding with vegetal mass of tangential threshing system to Romanian combine C110.

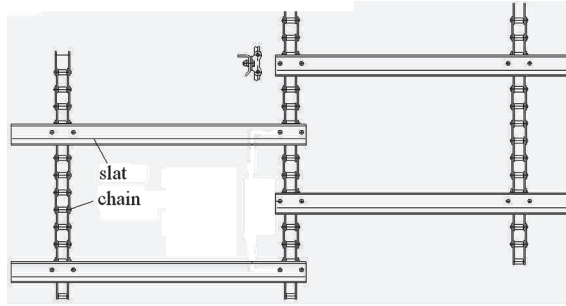


Fig. 9 Mounting interlaced slats on the conveyor chains at combine C110 [3]

For the following values of characteristics to combine C110: $q=3.9 \dots 6.2$ kg/s, $p=0.16$ m, $\alpha=29^\circ$, $r_1=0.096$ m, $r_2=0.118$ m, $D_d=0.142$ m, $z=8$, $\theta_{\text{optim}}=3\pi/4$, $L_f=0.040$ m, $n_c=960$ min⁻¹, $R_c=0.3$ m, result: $m_s=m_b=0.162 \dots 0.258$ kg, $t_{\text{feeding}}=t_{\text{optim}}=0.0235$ s, $n_{cv}=917$ min⁻¹, $S=41.6$ mm, $L_{\text{plant}} \leq 0.471$ m, $q_{\text{max}}=11$ kg/s. But, the chain gear wheel conveyor rotation speed do not exceed $n_{cv}=518$ min⁻¹, for technical reasons related to the conveyor chain

characteristics. In these conditions the capacity of combine threshing C110 has the value of $q = 5.5 \text{ kg/s}$.

To uniform threshing system feeding with vegetal mass at combine C110, we can be achieved by reducing the step of slats conveyor or we can mount interlaced slats on the conveyor chains (Figure 9).

CONCLUSIONS

According to the mathematical model presented, the speed of conveyor should be correlated with speed of threshing cylinder. The majority conventional cereal combine harvesters do not respect that requirement, feederhouse conveyor speed is constant, while that the cylinder has a variable speed, depending on the crop harvested.

According our informations, a single combines producer respects this condition (Deutz Fahr, Topliner models), other producers resumed to increase the number of conveyor chains and slats.

For C110 combine, the threshing process optimization at wheat harvesting, will get the rotation rate of conveyor chain gear wheels $n_{cv}=917 \text{ min}^{-1}$. At this value, the threshing capacity of combine C110 will be $q_{\max}=11 \text{ kg/s}$.

For the rotation rate of conveyor chain gear wheels $n_{cv}=518 \text{ min}^{-1}$, resulting $\theta=270^\circ$ (the optimum angle being at the combine C110 from $\theta_{\text{optim}}=135^\circ$), the feeding with vegetal mass of threshing system is being discontinued, and the threshing capacity will be $q=5.5 \text{ kg/s}$ (Figure 8). This value was obtained at the tests of C110 combine.

The compliance of this condition for C110 combine, should be determined changes of feederhouse conveyor construction and transmission, both solutions being considered to expensive for Romanian producer. The only thing I could do was to mount interlaced slats on the conveyor chains for the threshing system uniform feeding with vegetal mass.

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HISTORICAL CARTOGRAPHY AND GIS TOOLS FOR THE ANALYSIS OF LAND USE AND LANDSCAPE CHANGES

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SUMMARY

The human activities led modifications, connected to land use changes, in the agro-forestry areas and in the rural land. The changes in social and economic conditions, occurred during the last century, have imposed significant modifications to the rural land, with different impacts on the environment. To understand these modifications is now more easy thanks to new tools and technologies. The territorial analysis shows, with the support of a Geographic Information System (GIS) and historical maps, the dynamics of land use occurred during the years, in order to evaluate the consequences of the land transformations on the rural environment and landscape. The study area, located in the Basilicata region (South of Italy), reflects the common dynamic present in many rural areas of Southern Italy, i.e. the increase of agricultural areas (in particular for cereal crops) replacing forested surfaces in an older period, followed by the further phenomenon of spontaneous re-naturalization of many of these areas, due to the abandonment of extensive cultivated areas. The use of three-dimensional reconstructions, obtained through the creation of different Digital Terrain Model (DTM), has allowed to appreciate also the landscape modifications, in term of morphological and vegetation variation and aesthetic quality. A particular attention is required in land use management and agricultural activities, since they may influence some natural cycles of the ecosystems and the quality of the forest.

Key words: Historical maps, land use changes, landscape modification, rural land

INTRODUCTION

The analysis of the rural land modification, as well as its environment and landscape, is important in order to understand the profound transformations connected with the human intervention and natural events (Statuto et al., 2014). An analysis of land-use and land cover changes is fundamental to the understanding of numerous social, economic and environmental problems and can be carried out rapidly, using either cartographic or census data (Pelorosso et al., 2009). Multi-temporal analysis of land, with the support of GIS and historical document, is a very important tool for monitoring landscape diversity and investigating changes in vegetation and landscape structure (Statuto et al., 2013). Analysing land use changes generally requires an integrated approach that considers multiple disciplines, data sources and methodological constructs (Mutoko et al., 2014). Human activities imposed transformations of the extra-urban land and an accurate analysis of performing variations and a global monitoring of ecosystems seem necessary in order to propose environment protection politics and sustainable growth of the civilized World (Tortora et al., 2006). The relationship among agriculture, ecosystems and environment were proposed by some authors (Tassinari P., 2006; Adinarayana J. et al., 2006) as new contributions to territorial landscape planning and management. Many of the processes of land evolution and transformation are almost imperceptible when viewed over shorter periods, but in the long term they may well lead to changes in the carrying capacity, water balance and usability of the landscape (Haase et al., 2007). Rural, forestry and aesthetic changes may affect different components of the land and modifications of rural areas are certainly an important variable in the planning of landscape. During the past two decades three phenomena are re-drawing the configuration of rural areas: the mechanization, the accelerating demise of traditional rural life and an increase in the mobility of individuals (Domon, 2011).

Image processing techniques and landscape pattern metrics were applied to quantify the changes in forest cover patterns, while appropriate statistical descriptors were adopted to investigate the relationship between land-cover changes and topographical factors. The visual impact of some agricultural practices on the landscape has been recently considered. Land abandonment and the loss of traditional land-use systems are widespread in most of Mediterranean Europe, this situation occurred mainly in mountainous areas with a significant loss of agro-forestry ecosystems.

New systems for the rational collection and analysis of forestry and agricultural land data are now available. GIS-based techniques, Image Processing, remote sensing and other new technologies for the survey, planning and management of land evolution are enabling a more accurate analysis of rural landscape and environment (Picuno et al., 2011). In particular, Geographical Information System (GIS) are excellent tools for landscape modeling and three-dimensional analysis. They allow an easy digitalization of geographical information and coverage structure, as well as facilitating graphical representation. A GIS approach for territorial analysis, comparing historical maps with contemporary maps, is necessary to understand the landscape dynamic (San-Antonio-Gomez et al., 2014). Starting with the use of historical data and GIS methodology, for evaluating land use changes, reforestation and their implications for landscape and ecological impacts (Tasser et al., 2007), it is possible to understand as human and ecological variables mainly influence

natural reforestation of abandoned areas, combining techniques from land-cover change analysis, count data modelling and traditional fieldwork measurement techniques.

METHODS

Study area

The study area is located in Southern Italy, in Basilicata Region. It spans about 18 km², covering one part of the “Forenza” Municipality (40° 47' 57" N, 15° 51' 39,4" E, datum WGS84) (Fig. 1). The area embodies the territory represented by an historical cartographic map dating year 1829, that was used to assess the land use change. The study area is characterized by different watersheds that flow into the “Bradano” River, a hilly topography often characterized by high slope, forest and natural land.



Figure 1 Study area located in Basilicata Region within Forenza’s Municipality

The altitude of the study area ranges between 92 and 450 m a.s.l.. The soil structure have determined the various orography of this area, which has influenced the socio-economic context and agricultural activities. Moreover the wooded area, superficial water resources and groundwaters have contributed to the conservation of biodiversity. Forests are mostly dominated by deciduous oak wood (mesophile and meso-xerophile), while there are some conifers into an artificially reforested area; the herbaceous layer is very rich in species, it allows the penetration of a considerable amount of light.

Forenza's Municipality offers employment mainly in agricultural activities, many farms present in this area work on livestock activity and on cereal crops. The largest profit comes from cattle breeding and in particular by transformation and sale of dairy products. Moreover, fodder, olive groves, orchards and vineyards cover the hilly territory.

Cartography

Land use change and geographical reconstruction of landscape were carried-out over a period of 179 years in two time steps: 1829 and 2008. It was examined the specific cartography for each time with the aim to create different base maps that were analyzed within a GIS-approach. The historical map of year 1829 was manually drawn and represents part of Forenza Municipality "*San Giuliano's Wood*" (fig. 2). It was produced after border disputes in year 1829 by legal experts to solve division of domains. It was firstly scanned, imported and georeferenced in a GIS system.



Figure 2 Historical cartographic map dated 1829

The study area was divided into two parts, assigned to the municipalities of Forenza and Acerenza, the division was realized according to land surveying techniques of that period. The analysis of land use is based on chromatic differences between the territory of Forenza and Acerenza municipalities; hydrography is colored in the light-blue, forest is represented

as some tree-like symbols irregularly distributed. Road network is pictured into two different ways, farms and building have been reproduced considering the real aspect, in fact it can be distinguished various building types (farms of different sizes, a church, a butcher shop, caves and corrals). To determine land use of the year 2008 orthophotos were utilized. They combine the image characteristics of a photograph with the geometric qualities of a map. Each orthophoto is made up of four RGB visible bands or near-infrared with an average pixel value of 0.5 m. The projection is over the Italian geodetic system "Gauss-Boaga – Roma 40".

Data Analysis

With the aim to analyse the evolution of land use in different time the maps were converted into data and different categories of land use were identified; the number and features depend on the cartographic base. To compare the land use layer the different categories were aggregated into 5 classes. The most important categories identified in the study area are: *Natural land*, forest and transitional woodland-shrubs; *Agricultural land*, includes all types of cultivated areas, arable lands, vineyards, olive groves, permanent crops like orchards, permanent pastures and natural grassland, natural pastures with spontaneous herbaceous vegetation; *Urbanized area*, includes the new and the old farms, buildings and artificially surface; *Road network*, includes provincial and municipal roads and *River*, includes the bed of *Bradano* river and the vegetation present along the river. For each category the total area expressed in hectares (ha) and the percentage of its variation over the years were calculated. Through the digital processing of the maps it was possible to reconstruct the three-dimensional shape of the land, thanks to a photo-mosaic procedure and the virtual reconstructions of the land during different time periods. Recently, 3D visualization has been receiving more attention as a useful tool to understand engineering phenomenon or to detect important elements that cannot be found in usual simulations. A visualization in a virtual environment is a useful method that allows people to appreciate archaeological or historical objects through the computer. Moreover the land use of 1829 was correlated with the visualization of land use as in the aerial photos (1955) obtaining an historical reconstruction of the year 1829 landscape with a virtual jump 126 years-back, thanks to an *ante litteram* flight (since at that time airplanes did not exist yet). By doing so it is possible to appreciate qualitatively, in term of morphological and vegetation variations, the agro-forestry landscape changes, starting from a comparison between three-dimensional reconstructions of the study area during different years.

RESULTS AND DISCUSSION

From the superimposition of the different base maps it was possible to identify the different categories of land use. The study area consisted of 57.4% natural area, 40.5% agricultural land, 1.1% river, 0.9% road network and 0.1% built up area in 2008. The percentage of natural land decreased from 66.4% in the year 1829 to 57.4% in 2008 while, on the other hand, agricultural land increased from about 31% in 1829 to 40.5% in 2008. The river area decreased during the years, as well as the road network extension has significantly increased (fig. 3 and tab. 1).

The main difference occurred, following a widespread trend detected also in other different areas of Basilicata region, as a mutual exchange between the areas for agriculture and crops, that has reduced, so giving more space to the natural area (Tortora, 2015).

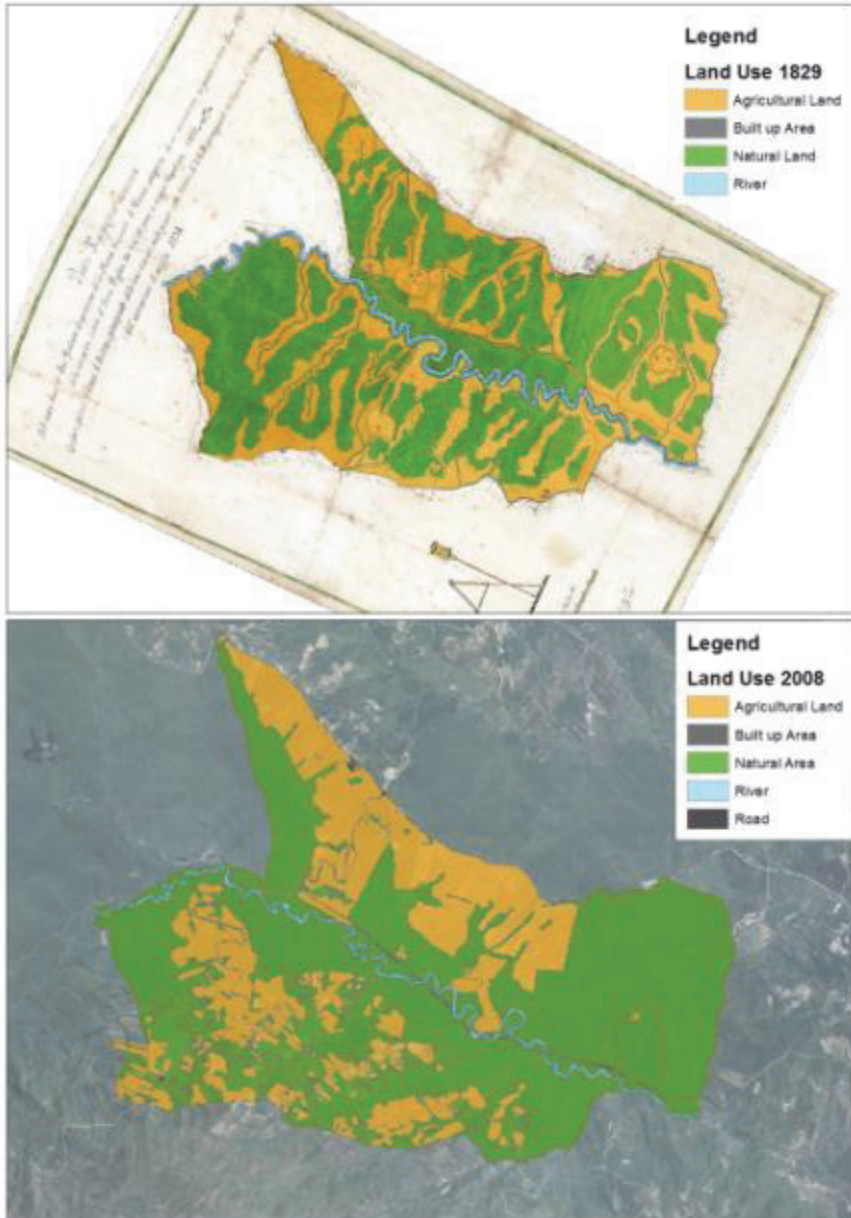


Figure 3 Land Use analysis (1829 - 2008)

Table 1 Analysis of different categories of land use

Years	1829		2008	
Land Use categories	ha	%	ha	%
Natural Land	1211.6	66.4	1047.3	57.4
Agricultural Land	570.3	31.3	738.1	40.5
River	40.9	2.2	20.2	1.1
Built up area	0.8	0.1	2.1	0.1
Road network	-	-	15.9	0.9
Total	1823.6	100	1823.6	100

Regarding farm buildings present in the study area the analysis shows an increase in their number and covered surface. Farm buildings play a central role in the environmental characteristics of agricultural land. Over the centuries they have accompanied the development of the agricultural activities (Picuno, 2012).

Land use maps and digital terrain model (DTM) may be adequately treated within a GIS in order to create, through spatial analysis procedures, some three-dimensional views, which may be used to appreciate the morphological and aesthetic landscape variations. The overlapping of different thematic maps provides an additional database that enables a comparison between different years.

With the support of GIS technics and historical documents it has been possible to analyse the land use changes that modified the study area during those 179 years. The analysis starts from the land use situation in 1829; the landscape of study area at that time was especially characterized by oak wood in which there were areas with a less forest density canopy, where it was performed the predominant agricultural activity of Forenza municipality: the livestock. Therefore there was an increase of arable land, the diffusion of an extensive agriculture and the improvement of cultivation techniques that determined a change in the landscape structure. Consequently, with the increase of agricultural activities, roads and buildings increased around to the double. The analysis has allowed making an assessment of the land use evolution, on landscape changes and environmental modifications, during the years, that were investigated in term of vegetation, environmental and visual impact. In 1829 the forested areas were the main component of landscape; the landscape quality was very high as for naturalness, biodiversity and aesthetic quality (fig. 4). Land use changes and deforestation had involved a significant change in the visual quality of rural landscape.

Comparing the situation in the year 1829 to the year 2008, the natural area within the Forenza municipality has decreased during the analyzed time period to give more space to the agricultural land (fig. 5), but in the recent years it occurred a common phenomenon widespread in the South of Italy and particularly in Basilicata region: the re-naturalization of the abandoned agricultural areas.

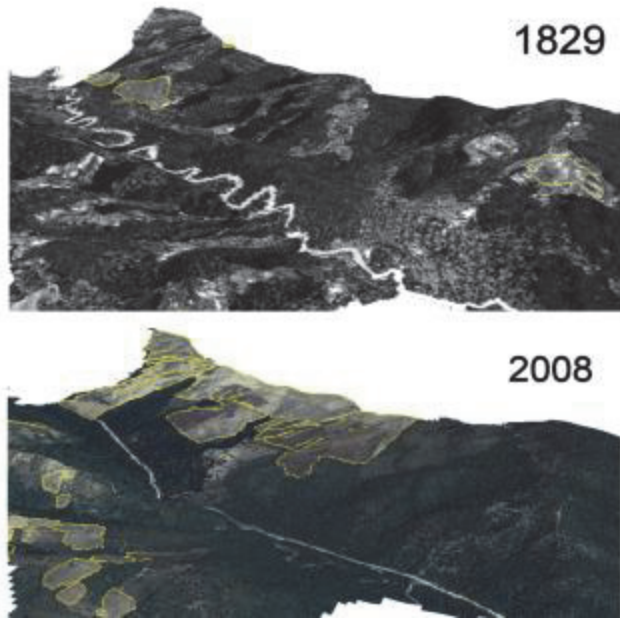


Figure 4 Comparison of three-dimensionally reconstructed land in the two different periods

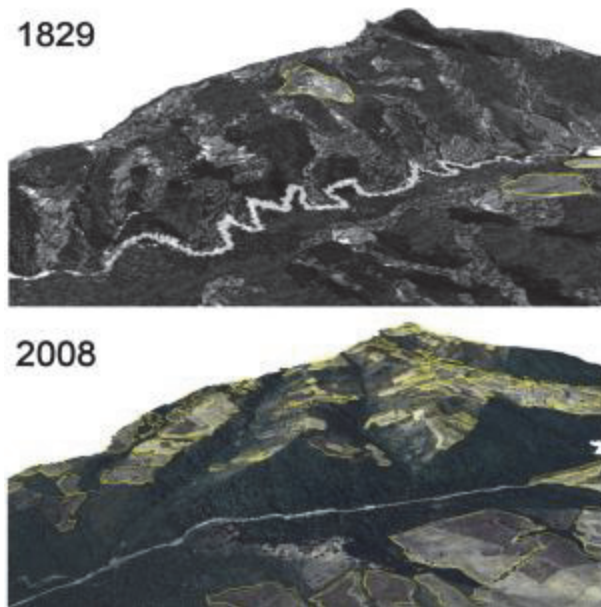


Figure 5 Visual reconstruction of the reduction of natural area and increase of agricultural land

This trend reflects the agricultural reforms and the socio-economic changes, which have also led to change of agricultural activities; the cereal crops replaced the pastures with the consequent modification of the landscape structure over the years.

CONCLUSIONS

The landscape, the environment and the rural land were subjected to significant and frequently impactful modifications and often they are the subjects of new agricultural and environmental policies. These dynamics require detailed studies that can be considered as decisive tools for the creation of appropriate instruments for the representation of all the aspects characterizing the agro-forestry land. In this study the historical analysis shows significant changes occurred in the study area in terms of land use, due to the continuous transformations of its landscape.

The abandonment of arable land is steadily increasing, due to the crisis in the agricultural sector, and it necessarily takes into account this phenomenon in the land management policies, because it can cause social, economic and environmental impacts. After land abandonment, it is possible to notice different phenomena such as biodiversity loss, increase of fire frequency and intensity, soil erosion and desertification, loss of cultural and/or aesthetic values, reduction of landscape diversity and reduction of water provision. The impact of these factors depends on the territory conditions, and it is not equally significant in all geographic regions. In order to reach a correct evaluation, it is important to contextualize the impacts in relation to the soil, to the dynamics of land use and to the socio-economic conditions of the area. This is possible thanks to the GIS-methodologies, able to build specific models for study areas, which can be used for the assessment of landscape and environmental changes. The Geographic Information System (GIS), allows the implementation of historical models, for quantitative and qualitative studies, enabling the understanding of the evolution of landscape and rural land, with the aim to address correct spatial planning e proper land use management policies. The extraordinary properties of representation, offered by these modern information technologies, increase the perception of the study areas and improve the informational aspects and the opportunities of visual simulation of the land use evolution. For the process of abandonment of this study area further studies are required, in order to evaluate risks and to develop a more sustainable land management. The use of this multidisciplinary approach, based on the historical maps, historical documentation and modern cartographic base, allows to understand the landscape evolution, its possible future trend, through its principal environmental and socio-economic components, and to address proper land use policies and guidelines for sustainable land management.

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POSSIBILITIES OF USING SPATIAL ANALYSIS (GIS) AS AN INPUT DATA TOOL FOR THE GREENHOUSE DECISION SUPPORT MODEL

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ABSTRACT

Greenhouse production system is a system that needs a good management. If on the beginning things are not clear to the producer the greenhouse system will not work properly and it would be economically and energetically unstable. Before starting the greenhouse business the farmer must have an idea what he wants, what is he capable of and what are his resources. In this paper, an improvement of a simple model as decision support model for the greenhouse production system is presented. The basic idea of the algorithm was to offer to the producer an adequate solution of the greenhouse production systems regarding the greenhouse construction type and technical systems with their capacities, based on his elementary idea. In sense of user friendly working environment, spatial analysis (GIS) was introduced as a possibility of serving as an input data tool for the model. Based on the farmer / producer location algorithm itself draws the data from the various orographic characteristics such as slope of the terrain, exposition, soil type, soil quality, underground waters and weather conditions for the specific location and thus provides to the farmer / producer necessary input data in the short period of time.

Key words: greenhouse, algorithm, spatial analysis (GIS), model

INTRODUCTION

Greenhouse production is a very complex production system that needs to be maintained well with great attention. Decision about starting this kind of business involves great number of variables that need to be analyzed. Since their introduction in the middle of the 20th century, greenhouses passed various phases of development in sense of improving the

covering material, construction and production technology and process control (Van Hanten, 1994; Nelson, 2003). Ordinary agricultural producer, when trying to start the greenhouse production system, if not guided well can easily give up the idea (Smith et al., 1997). At present, when starting the greenhouse production project, farmer contacts people from the Faculties of Agriculture, but more often, they consult the equipment trading companies. Whatever his choice is, it is suitable to have some kind of idea of the potential location, surfaces, kind of greenhouse construction etc.

In the past, lot of research has been done concerning the modeling of the greenhouse production system and processes. Optimal computerized control of greenhouses using information about crop growth is well underway in the research community (Bennins et al, 2008). Most of the research is focused on controlling the greenhouse climate (Van Straten et al, 2000, Bennis et al, 2008, Blasco et al., 2007, Speetjens et al, 2009, Van Henten, 1994, Molina-Aiz et al, 2010, Ehret et al., 2011). The other part of research is dealing with controlling the processes like irrigation, fertilization and plant protection (Helmer et al, 2005, Massa et al., 2011, Aggarwal et al., 2006). There are few researchers that are dealing with complete greenhouse growth models that incorporate greenhouse climate control, processes optimization, plant psychology and energy consumption (Clarke et al., 1999, Incrocci et al., 2006, Gupta et al, 2010).

A simple model as decision support model for the greenhouse production system was made that is able to give a start-up idea for any producer that wishes to start this serious business (Dimitrijevic et al., 2012a). For using this model farmer must have a PC computer and Microsoft Excel software installed. For the adequate operation model uses input parameters and the knowledge sources. Analyzing this model (Dimitirjevic et al., 2012b) it was concluded that the model is too time and knowledge consuming for the farmer. Some farmers are not in position to know the soil quality of an area where they want to establish their production. They have no means to visit and explore new available surfaces. In sense of facilitating input of data needed for the model, the idea of using the spatial analysis (GIS) was proposed. The idea was to upgrade the previously made decision support model (Dimitrijevic et al, 2012a) using GIS in sense of getting data about the location, soil quality and microclimatic parameters. In this paper the basic working principle of the model is presented and the upgraded parts analyzed.

MATERIAL AND METHOD

The model has its base in database regarding available greenhouse constructions, covering materials, available types of irrigation systems and their characteristics as well as of heating systems and ventilation. For the model preparation few main questions were used as its base.

The first group of questions was based on the chosen fruit/vegetable production and production surface that is on disposal. The new segment of the model facilitates the data about the available surface. The question about the available surface doesn't need to be answered by farmer but by using GIS. Knowing the location and having access to the maps the data about the surfaces can be automatically loaded. These questions are used in model for formulating the greenhouse type of construction, its dimensions and orientation.

The second group of question was based on production technology, the time of harvesting and soil quality. Previously farmer was asked to enter the data about the soil quality. In that sense the soil quality analysis were necessary before starting the model. Since this is not an one-hour job, the idea was make it simpler. Soil maps will be used to give the answer about soil quality parameters and terrain exposition. These questions are used in model to give an answer about the time of planting and the production technology that should be applied.

The third group of questions is based on construction, covering material, production technology and give the answers about the technical systems and their capacity. In this segment spatial analysis was used to provide the microclimatic data about the specific location, such as air temperature (minimum and maximum daily and monthly values), wind speed and direction as well as precipitations (rain, snow).

The forth group of questions is based on the production area and gives the answer about the additional surface for the storages, protective areas, parking areas etc. All these questions served as a formatting tool for the model algorithm. The question about the additional surfaces and the possibilities to expand the business is solved by the spatial analysis.

Based on all these input parameters, and output parameters obtained after the analysis, the model gives a final report with the exact data about the greenhouse type of construction, covering material, orientation, production are, time of planting, production technology, type of ventilation system, heating system, irrigation system and their capacities, as well as additional operational surface and protective areas. For the orientation and greenhouse type of construction model uses common recommendations given by the international standards (Nelson, 2003).

For the purpose of production technology determination another database that consists of the planting/harvesting dates for the moment most common vegetables, was made (Momirović, 2003). In this part of the model a database of the soil properties that would be optimal for the production (Momirović, 2003) was made and inserted to Excel. With the aim to decide the proper vegetation type, soil quality maps, that explain the most important parameter of the soil at the given location, can be used in order to see if the soil quality meets the plant species requirements.

Concerning the part about the choice of technical systems, standards about the ventilation rate (Nelson, 2003, Willits, 1993) were entered in the model. For the purposes of heating systems calculation, date base about the covering materials and type of the heating systems was made and incorporated in the model (Nelson, 2003, Martionv et al, 2006). In some case, it is possible to use meteorological data arising from stations located near the investigated area. For easier calculation of the irrigation system capacity a date bas about the currently available irrigation systems, suitable for the greenhouse production was made (Bajkin et al, 2005). This database includes the type of irrigation system and their technical specifications.

For the last, organizational part of the greenhouse model standards for the additional surface for storages, working space, parking space and security zones are inserted (Hanan, 1998, Nelson, 2003).

In a GIS System it is possible to insert all kind of these data with coordinates system that explains, for each location, the main parameters analyzed and also provides the information after the superimposition of different parameters.

RESULTS AND DISCUSSION

The first part of algorithm stays the same. Producer inserts culture and the desired production surface, and model suggests the type of greenhouse construction. The output data from this part of model are greenhouse orientation, production surface and the covering material/production surface ratio. Knowing the GPS coordinates is possible to obtain, in a GIS system, information about: terrain, slope, orientation, soil quality, carbonate content and pH, etc (Fig. 1).

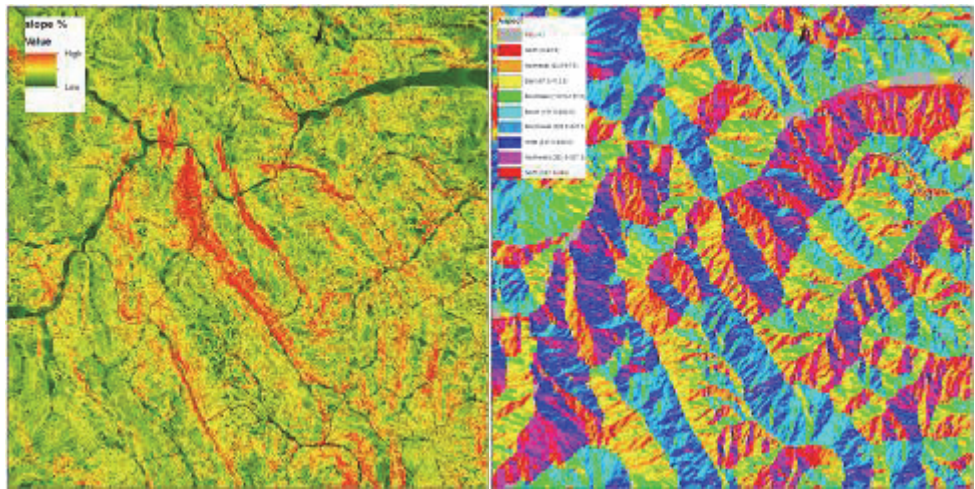


Fig. 1 Slope and exposition maps of an area located in Basilicata Region (South Italy)



Fig. 2 Input and output parameters for the production technology suggestion

Further part of the algorithm represents the part of choosing the production season and technology. Basically, user is asked about the time of harvesting and about the basic parameters of the soil quality (organic matter content, levels of nitrogen, phosphorus and

potassium and pH level). Analyzing the user answers model suggests the time of planting and the production technology (Fig. 2). In the new version of the algorithm farmers does not need to know the soil quality parameters, it is possible to understand the situation from specific maps (Fig. 3).

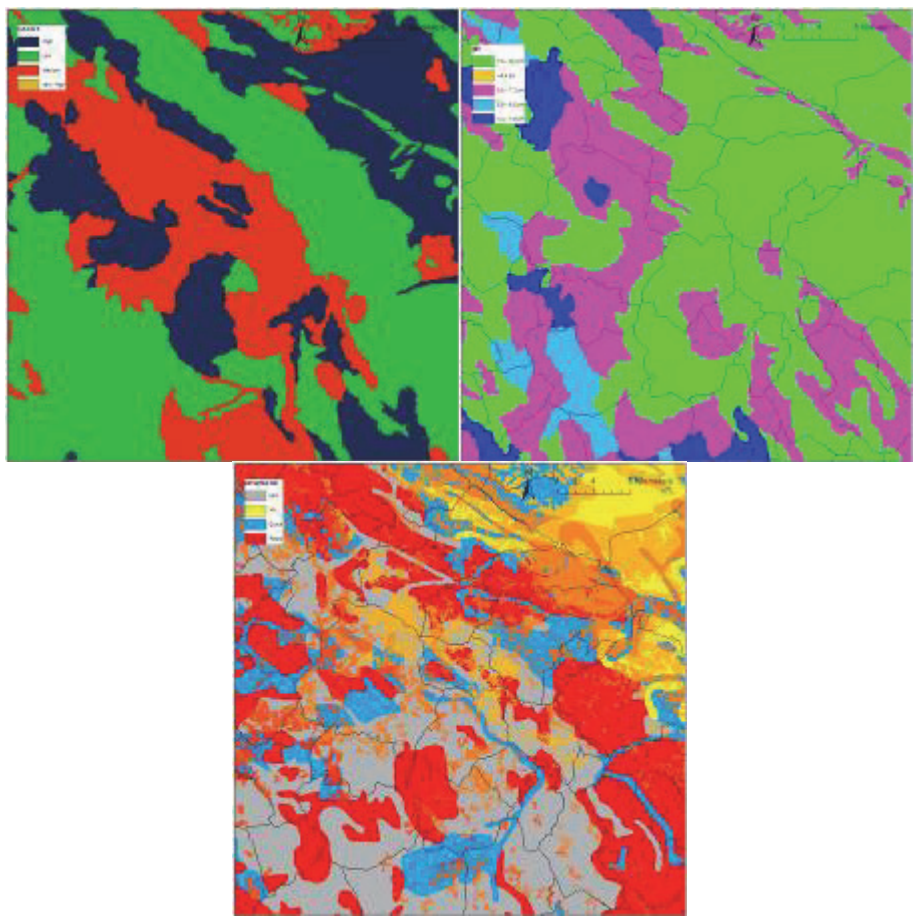


Fig. 3 Soil quality data – Carbonate, pH and drainage (Area located in Basilicata Region)



Fig. 4 Input and output variables for the ventilation system suggestion

In Figure 4, input and output variables for the optimization of the ventilation system are presented.

In this case model already has the needed values so this parameters is automatically calculated when construction, dimensions and surface of ventilation openings are known. The final output will be given through the capacity of a single fan (m^3/min) and their total number in the greenhouse.

In case of heating model suggests whether heating is needed or not. The input variables are already known except that the user must suggest what covering material will be used and what kind of heating system does he want (air heating, pipe central heating, etc.). Other input variables are wind speed and the temperature in the region (Fig. 5). Farmer does not need to know these because these data can be provided in meteorological station. The data collected are related to temperature, precipitation, wind speed and direction, etc.

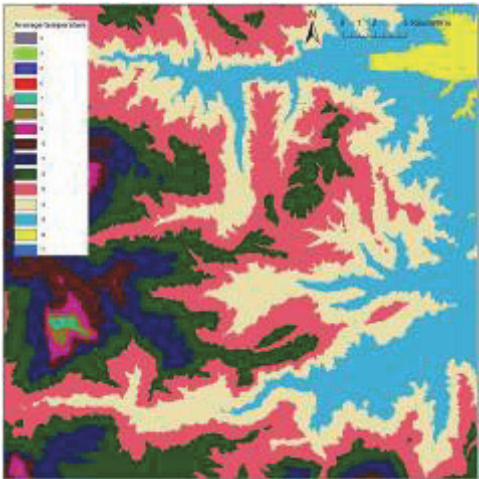


Fig. 5 Average Temperature in a region (°C)

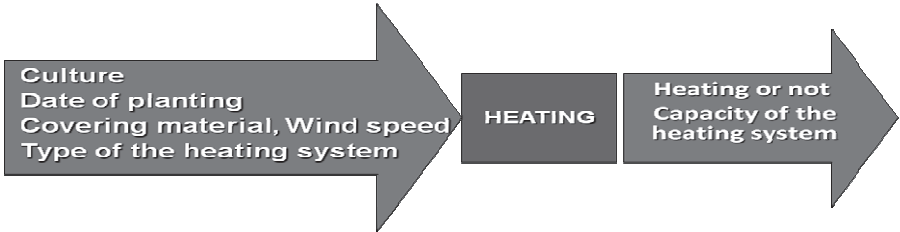


Fig. 6 Input and output variables for the heating system suggestion

Final output will be given through the heat losses of the greenhouse (kW) (Fig. 6).

Concerning the irrigation system, model already has some values. User must decide about the type of system (model suggests him concerning the plant production). After choosing the type user must decide how many irrigation cycles per day he wants.

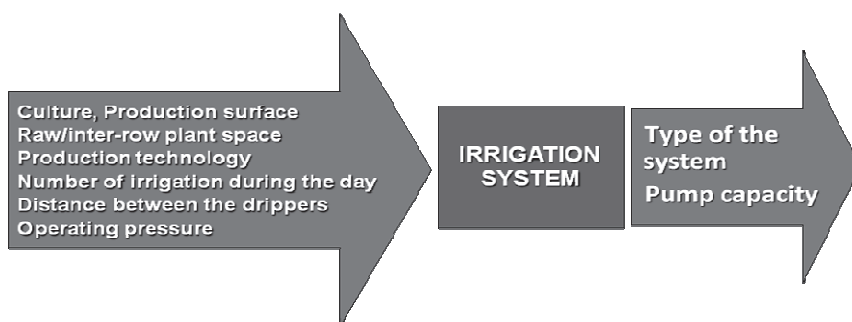


Fig. 7 Input and output variables for the irrigation system suggestion

The output of this step is what type of system did the user choose, what is the capacity of the system and of the pump and how much water per cycle does he need (Fig. 7).

Final step in the proposed model is to suggest what is the surface needed for the storages, working offices, protective area etc (Fig. 8).



Fig. 8 Input and output variables for the additional working area

In this phase user must give the data whether or not there is some working area around the future greenhouse and what the surface. Model compares to the standard recommendations about the surface of this area and suggests whether user must prepare totally new area or only to plan some more space.

During the algorithm implementation Excel program was used and it was found very difficult for using as a programming program. Based on the algorithm some other program must be use in order to adequately follow all parts of the algorithm. One of these can be Quick Basic or something similar. The use of spatial planning program that can compare and analyze spatial data to understand the proper characteristics of the area can be beneficiary in this case.

CONCLUSIONS

In this paper a simple model that is meant to be used by the ordinary farmers is presented. The aim was to closer the greenhouse production system to a farmer by letting him to know on what parameters he can influence and how changing the one parameter can influence the establishment of whole system. The idea of introducing spatial analysis as an input data tool, that will facilitate model usage, was presented. Possibilities of using spatial

data and thematic maps, such as soil quality, available surface and exposition, microclimatic condition, etc were analyzed and discussed. Proposed algorithm was realized in the MS Excel 2000 Program but during the realization some difficulties occurred, that indicate the need of using some other program, more suitable for spatial planning should be used, such as geographical information system.

ACKNOWLEDGEMENT

We would like to thank to the Ministry of Education and Science, Republic of Serbia for funding the TR 31051 and TR 31046.

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AIR DUST PARTICLES MONITORING IN A GREENHOUSE BASED ON THE ARDUINO

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SUMMARY

Our study presents a low-cost indoor air quality acquisition system, based on the Arduino YUN hardware platform and infrared LED dust sensor Sharp GP2Y1010; the hardware elements are detailed, together with experimental evaluation. This system was designed to be integrated in an environmental evaluation platform based on Arduino that will be used for monitors and control the environmental climate in a greenhouse. The tests revealed that the dust sensor selected provided excellent agreement with a far more expensive aerosol monitor. The systems air dust particles monitor proved to be an effective and economical tool for diagnosing air pollution problems. Future studies will concentrate on further developing our hardware, we will aim its integration in a prototype system for the environmental evaluation platform.

Key words: air quality, greenhouse, dust sensor, Arduino YUN.

INTRODUCTION

Air pollution is one of the top causes of death in Europe, which in 2010 led to the premature death of over 400,000 people within the European Union, said the European Commission, in a recent statement. However, poor air quality leads to illness and therefore increases medical costs and reduces economic productivity. However, air pollution affecting the crops and buildings, recalls EC.

Air pollution in the free space in the most extreme cases, can be identified immediately, without any special training. It is manifested by fog on cities, is deposited on streets and buildings, and offers dramatic news topics.

Even when air pollution is not really visible, we can feel when something is not right. Studies of human exposure to air pollutants set by EPA-US indicates that the levels of

pollutants in enclosed spaces can be 2 to 5 times - and occasionally more than 100 times - higher than outdoor pollution levels free. Indoor air pollutants were ranked among the top five environmental risks to public health. The problems caused by them can be subtle and do not always produce immediate or recognizable on health.



Figure 1 ArdieDust

Introducing easy-to-use microcontrollers such as Arduino, led to the availability of digital electronics devices extensively in the study of air pollution. Arduino projects and similar initiatives have generated a growing number of studies detailing the basic principle of using these devices and sensors in environmental and agricultural sciences. Khadem and Sgarciu (2011) have developed a network of intelligent optical sensors to monitor and measure the dust from urban and industrial environment. They use wireless sensor networks that are connected together in sink nodes. All nodes transmit information to the main server where they are processed and stored in a database monitoring. Budde et. al. (2012) investigates the feasibility of particulate matter measurements using cheap, commodity dust sensors which are small enough to be incorporated into mobile devices. Olivares et. al. (2012) study the evolution of domestic indoor air quality (particles, carbon dioxide, temperature and movement) associated with source activities in the home with four prototype instrument packages based on Arduino Pro Mini and some intelligent sensors.

The device constructed named ArdieDust is intended to operate as a device capable of generating environmental data sets, and also demonstrate the ease of development of useful applications using Arduino as a base system. This paper describes our design approach and process up to the point of building and testing. It presents the results of an evaluation of the prototype in a series of controlled experiments.

METHODS

In the specialized literature for determining dust emissions come together two broad categories. These are optical systems and tribo-electric systems. In these two groups are a numeral of dissimilar cases of instruments, all of which demonstrate similar performance features. Optical sensors respond to the mass concentration of dust within the duct. Light

beams are influenced by the scattering characteristics of big numbers of small molecules and the measured parameter is influenced by the number of particles per unit volume of air, which in turn is proportional to the mass concentration.

Light scattering is a consequence of the interaction of light with the electric field of a small particle or molecule. An incident photon induces an oscillating dipole in the electron cloud. As the dipole changes, energy is radiated in all directions. This radiated energy is called “scattered light”. Formal light scattering theory may be categorized in terms of two theoretical frameworks (Gupta, 2011). One is the theory of Rayleigh scattering that is, strictly speaking as originally formulated, applicable to small, dielectric spherical particles. The second is the theory of Mie scattering that encompasses the general spherical scattering solution (absorbing or non-absorbing) without a particular bound on particle size. Accordingly, Mie scattering theory has no size limitations and converges to the limit of geometric optics for large particles (Hahn, 2009). Mie theory applies to scattering of plane waves of monochromatic light by isotropic spheres. Isotropic materials, incidentally, have properties that are independent of the direction in which they are measured. The intensity of the scattered light is a function of the wavelength λ , the scattering angle θ , the particle size d , and the relative index of refraction n of the particle and the medium. Symbolically, it can be described by a relationship of the form,

$$I = I_0(\theta, \lambda, d, n) \quad (1)$$

The principle of optical particle concentration measurement that we use Sharp sensor is based on the amount of reflected light beam of particles in the air. Transformation of dust concentration in a usable output size using a fixed light emitter is shown in the diagram in Figure 2. Beer–Lambert–Bouguer’s law describes the relation between the light transmission and the dust concentration c according to the following equation (Khadem et. al., 2012):

$$I = I_0 \cdot \exp(-\varepsilon \cdot c \cdot l) \quad (2)$$

where I represent resulting intensity of the light beam, I_0 - initial intensity, ε - coefficient of extinction, l - distance, and c dust concentration.

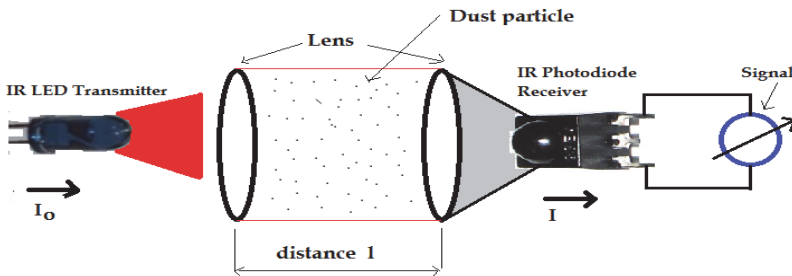


Figure 2 Optical principle of measuring the concentration of particles

Agreed requirements for our system have been: low unit cost; small form factor; non-intrusive in the environment. We also took the approach of designing around open source hardware and software in order to reduce the development time of this instrument. Late we conducted a review of suitable low-cost components available and settled upon an initial design concept. Arduino is one of the most easy to use microcontroller platforms. The hardware consists of an open-source hardware board designed around an 32-bit Atmel ARM microcontroller.

The YUN is a microcontroller board based on the ATmega32u4 and the Atheros AR9331. The board has built-in Ethernet and Wi-Fi support, a USB-A port, micro-SD card slot, 20 digital input/output pins that accommodate various extension boards (of which 7 can be used as PWM outputs and 12 as analog inputs), a 16 MHz crystal oscillator, a micro USB connection, an ICSP header, and a 3 reset buttons. The Arduino Yún is a very powerful, networkable Arduino combines the ease of Arduino programming with additional processor AR9331 running Linux and the OpenWrt wireless stack. The Arduino Integrated Development Environment (IDE) is a cross-platform application written in Java, and derives from the IDE for the Processing programming language and the Wiring projects. Arduino programs are written in C or C++. The Arduino IDE comes with a software library which makes many common input/output operations much easier. ThingSpeak is an open source “Internet of Things” application and API to store and retrieve data from things using HTTP over the Internet or via a Local Area Network.

The proposed system (fig.1) is an embedded system which will closely monitor air quality parameters of a greenhouse on a regular basis round the clock for cultivation of crops or a specific plant species. When dust levels inside the greenhouse varies, the sensors sense the change and the microcontroller read this from the data at its input ports after been converted to a digital form by the ADC. We used a small 40mm fan (5V) to help make sure the air was circulated thru the Sharp sensor. To reduce the voltage from external DC power supply we use an LM2596 Step Down Power Module converter. The system also employs an OLED monochrome 128×64 dot matrix module to display information retrieved from sensors and alerting the user about the air quality evolution inside the greenhouse. Thus is designed as an easy to maintain, flexible and low cost solution. Figure 3 shows the main components of the system.

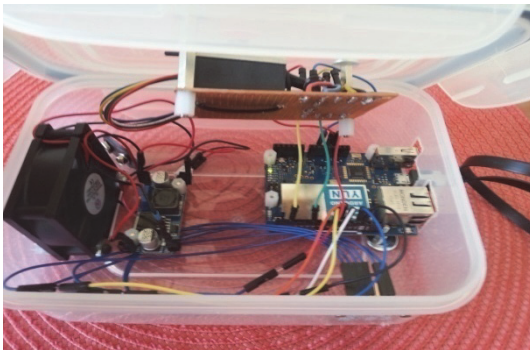


Figure 3 Main components of ArdieDust



Figure 4 Dust Sensor

Sharp dust sensor “GP2Y1010” (fig. 4) is the device to detect house dust, cigarette smoke, etc. In this sensor an infrared emitting diode and a photodiode are diagonally arranged to allow it to detect the light scattered by dust in the air. It is claimed to be especially effective in detecting very fine particles like cigarette smoke, and is commonly used in air purifier systems, but because it doesn't include any sizing system, it is not possible to assess the cut-off size of its measurements (Olivares, 2012). Figure 5 shows how the device works when dust exists inside of it. Current in proportion to the amount of the detected light comes out from the detector and the device makes analog voltage output after the amplifier circuit amplifies the current from the detector. The more particles there are in the detect region, the more light is reflected to the light-receiving element.

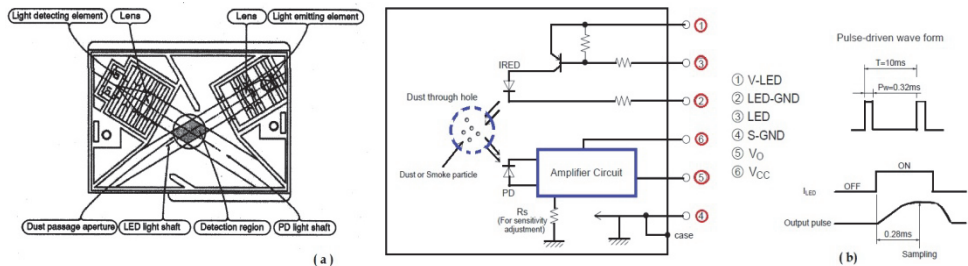


Figure 5 Optical Sensor (a) Schematic principle (b) PWM Excitation (Sharp, 2006)

The YUN board has the task of enabling the duty cycle of the command for the optical sensor LED according to the pattern in Figure 5b. Basically, a digital output controlling the LED of the detector has to be set to low for 0.32 ms in a 10 ms time period, afterwards an analog voltage output can be read. The computer analyses were done with the mathematical software packages MATLAB.

RESULTS AND DISCUSSION

The experimental work has deployed in the greenhouse, available in UPB campus, Depart. of Biotechnical Systems (with 30m*6m dimension) in order to monitor the environmental climate conditions. In order to provide natural ventilation greenhouse was rolled a portion of the side wall to obtain a suitable air flow. According to the following results obtained, the designed system presented gives excellent results and monitor efficiently air quality in our greenhouse.

At first, in a few days was a test calibration measurements with device design. The signal obtained was stable, but influenced by noise due to the microcontroller power supply as may be noticed in Figure 6. Source was replaced and things went back to normal.

Over the course of three days (16-18 August 2014), the dust sensor was deployed in the greenhouse locations. Every 15 seconds, the YUN board would take a reading from the sensor, interpret the reading in terms of mass concentration, and send that data via a Wi-Fi network to a ThingSpeak server (figure 7). Once the Arduino Yún is connected to Wi-Fi, the Arduino has full access to ThingSpeak Cloud Services.

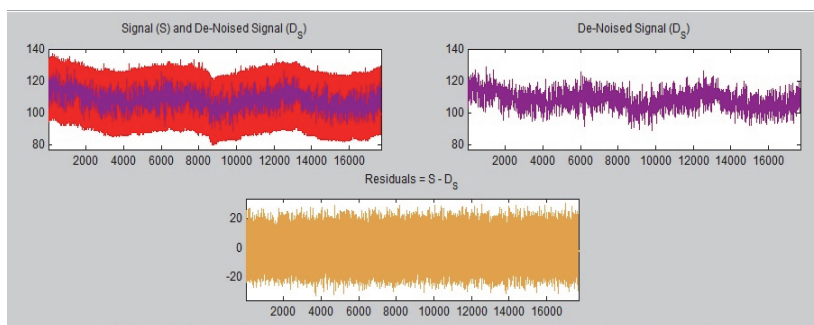


Figure 6 Trials of the ArdieDust

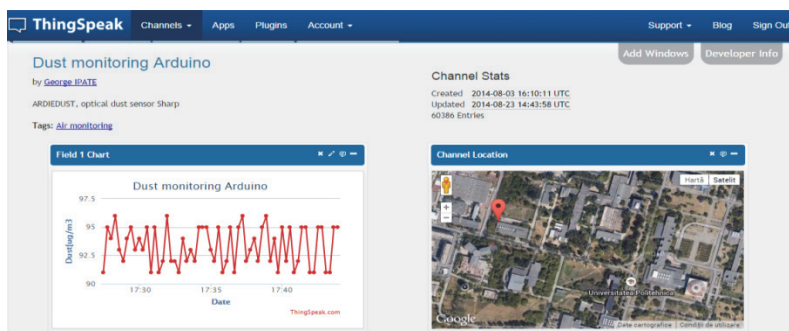


Figure 7 ThingSpeak Cloud Service

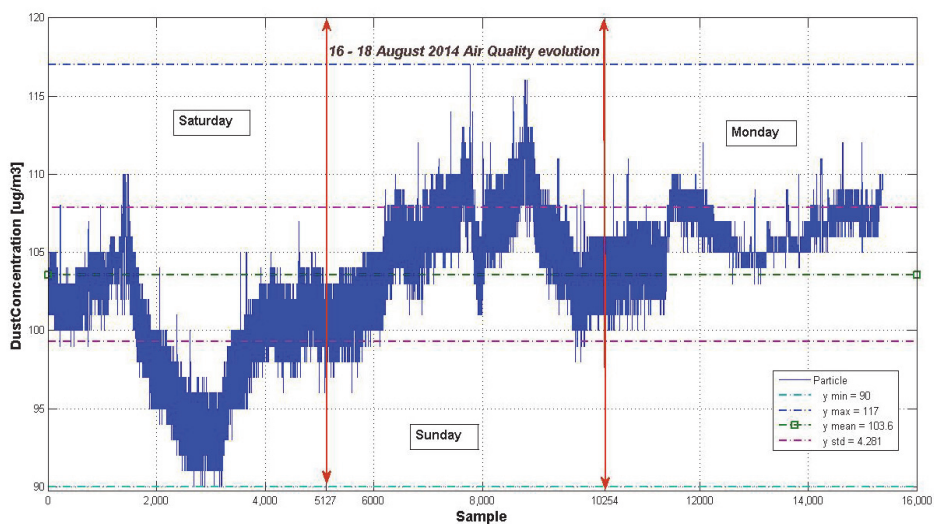


Figure 8 Air Quality evolution

After all the data was posted, we queried the ThingSpeak server to send back the data in CSV format (Comma Separated Value). We placed the CSV data into MATLAB script, which is used to analyze, compare and graph the data. Figure 8 shows the chart comparing the sensor readings in all three days.

It may be noted that dust concentration amplitude peaks were around $117 \text{ (ug/m}^3\text{)}$, minimum values obtained was $90 \text{ (ug/m}^3\text{)}$, the average value of the three days was $103.6 \text{ (ug/m}^3\text{)}$ with a standard deviation of ± 4.281 and a range of 27 units.

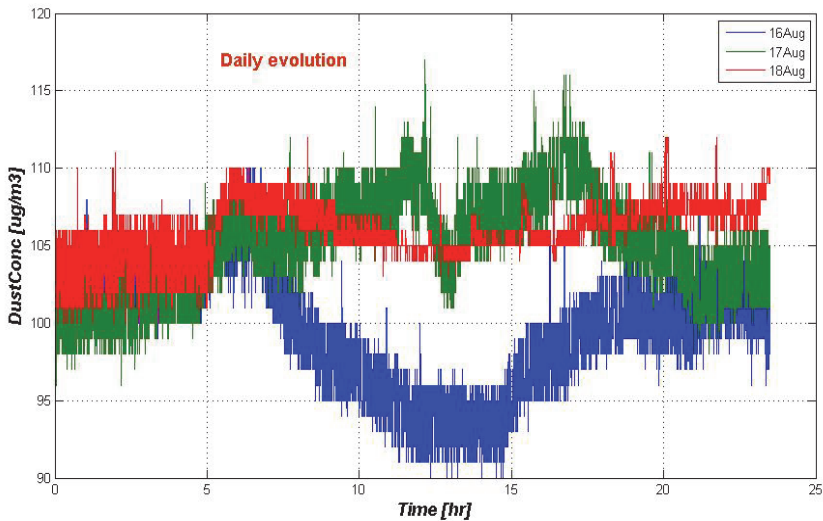


Figure 9 Compared measured data (16-18 Aug 2014)

In Figure 9 it can be observed hourly variation in the concentration of dust in the air every day. For all three days, the time interval 0.00-5.00 values are close, with an average of about $100 \text{ [ug /m}^3\text{]}$. On August 16, Saturday, the lowest values are obtained between the hours 10.00-15.00, when human activity is normally low. Mean interval stands at around 93 ug / m^3 . The highest values are recorded on the day of August 17, 117 ug / m^3 - at 12.00 and 16.45, when possibly due to increased human activities.

For exploratory data analysis, we used statistical plots shown in Figures 10 and 11. Figure 10 shows the box plot. The graph above compares values in samples from every day of tests. The tops and bottoms of each "box" are the 25th and 75th percentiles of the samples, respectively. The distances between the tops and bottoms are the interquartile ranges: 6 ug/m^3 -first day, 3 ug/m^3 -second day and 2 ug/m^3 - the third day. The line in the middle of each box is the sample median (100 ug/m^3 -16Aug, 105 ug/m^3 -17Aug, respectively 106 ug/m^3 -18Aug). If the median is not centered in the box, it shows sample skewness (Day16Aug).

Comparing box-plot medians is like a visual hypothesis test, analogous to the t test used for means. The whiskers are lines extending above and below each box. The long lower tail

and plus signs also show the lack of symmetry in the sample values. The mean (99.55; 105.18; 106.007) and median (100; 105; 106) values seem very close to each other. A negative skewness value -0.2805 (first day) and -0.3925 (third day) means the data are left skewed. The data do not have a higher peakedness than the normal distribution, because the kurtosis value (2.527; 2.556; 2.556) is less than 3. Notches display the variability of the median between samples.

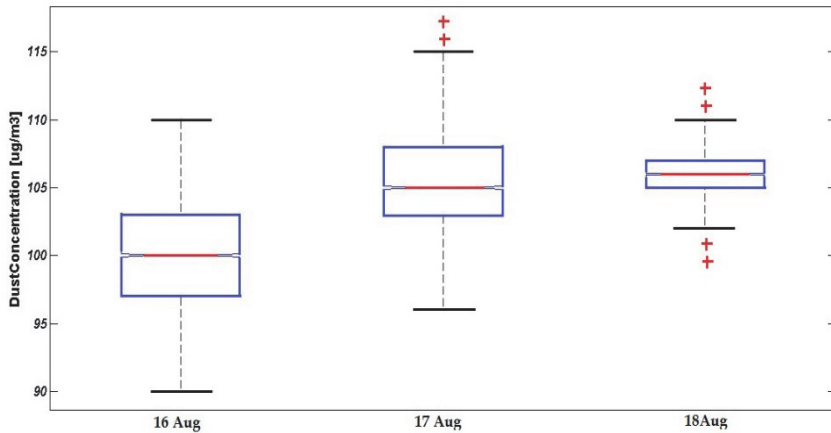


Figure 10 Box plot

To investigate different levels of grouping data, we created a hierarchical tree of clusters as can be seen in Figure 11. The cophenetic correlation ($c = 0.7671$) is one way to verify that the cluster tree is consistent with the original distances. Large values indicate that the tree fits the distances well, in the sense that pairwise linkages between observations correlate with their actual pairwise distances. This tree seems to be a fairly good fit to the distances.

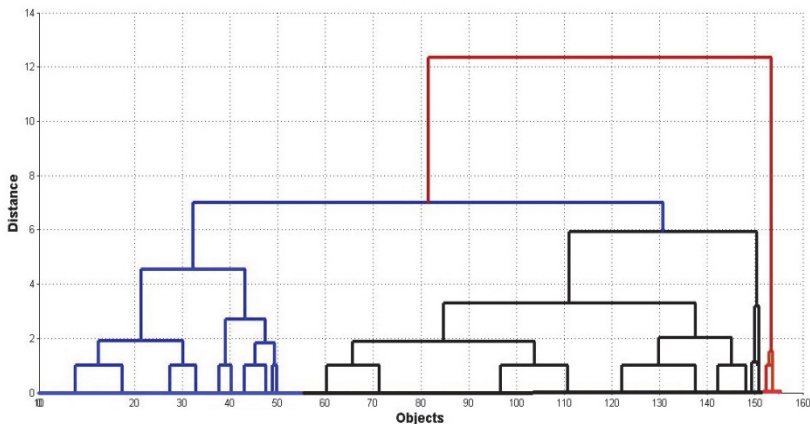


Figure 11 Dendrogram

The root node in this tree is much higher than the remaining nodes, confirming there are two large distinct groups of observations. Within each of those two groups, we can see that lower levels of groups emerge as you consider smaller and smaller scales in the distance.

Table 1. Air Quality Standards

Authority	Pollutant	Objective	Measured as:
EC/UK Air Quality Standard	PM10	50 µg/m ³	24 hr mean
USA National Ambient Air Quality Standard	PM10	150 µg/m ³	24 hr mean
EPA Air Quality Index	PM10	55 µg/m ³	24 hr mean
UK occupational exposure limit	Total inhalable fraction	10 µg/m ³ /day	Ave. over 8 hr period
USA National Ambient Air Quality Standard	PM10	150 µg/m ³	24 hr mean

Comparing the values obtained from measurements of air quality standards in Table 1 can be seen almost double peaks European standards, but within normal limits to US standards.

Table 2 System budget

Nr.crt	Parts	Qty	Price euro
1	Arduino YUN Board	1	80
2	Optical Dust Sensor Sharp	1	15
3	Display 0.96" OLED LCD 128x64	1	3
4	LM2596 Step Down Adjustable Converter Power Supply 1.5-35V	1	1
5	Dupont Wire 20cm 2.54mm	40	1
6	DC Brushless Cooling Fan 5V - 40mm	1	1.1
7	Plastic Box	1	1.8
8	Threaded PCB Hexagonal Standoff Spacer	20	4
	Total		106.9

The system budget is captured in table 2. The final system did not require the purchase of special mounting devices.

CONCLUSIONS

A low-cost instrument was designed to measure the concentration of dust particles, or data related to sources in context, in a greenhouse. The tests revealed that the dust sensor selected provided excellent agreement with a far more expensive aerosol monitor.

An understanding of basic concepts in signal processing and data manipulation will enable one to select instrumentation and to understand its use. The sensor signal is possibly influenced by the final application of the device. The method of mounting, the resonance frequencies of the whole circuit can affect the dust sensor signal.

By using a smart sensor, the designed instrument can monitor and measure dust in any environment, both indoors as well as greenhouses and in open spaces, and in this way we

can protect and ensure the life and health of workers and our citizens. The coverage area of a network of sensors to monitor the dust can be extended according to existing needs without significantly increasing costs.

ACKNOWLEDGEMENTS

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/132397.

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ECOSYSTEM SERVICES DEMAND, SUPPLY AND BUDGET ALONG THE URBAN-RURAL-NATURAL GRADIENT

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SUMMARY

Landscapes can be viewed as a continuum and studied using spatial gradients, along which environmental modifications are ordered in space and determine the structural and functional components of ecosystems. The anthropogenic land uses generate specific gradients that can be recognised along the succession of urban-suburban-cultivated-managed-natural landscapes. From this point of view, the traditional urban-rural dichotomy can also be considered as a gradient, produced by a sliding level of human influence on ecosystems. Since the Millennium Ecosystem Assessment (2005), many scientists are directing their effort to studying and quantifying the benefits people obtain from ecosystems, synthesised by the concept of Ecosystem Services (ES). One of the major approaches for ES assessment is based on the analysis of stock and the condition of the biodiversity of the usual components of habitat, ecotopes or biomes. Despite this increasing interest, spatially explicit methods to analyse ES are still lacking. The research aimed to develop an innovative methodology supporting landscape analysis and planning processes by means of (a) the identification and characterisation of the types of landscape along the urban-rural-natural gradient and (b) the analysis of potential ES demand and supply within said types of landscape. The Kernel Density Estimation technique was applied to calculate continuous intensity indicators associated with urbanisation, agriculture, and natural elements, considered as key components of the formation of the landscape gradient. A multivariate, spatial analysis enabled the identification of different landscape structures constituting the gradient of the study area. The classification highlighted not only specific "pillar" landscapes, dominated by one of the three components (urban, agricultural, and natural), but also transitional landscapes, where the most relevant relationships between land uses

were identified. The potential ES demand, supply, and budget within each landscape area were assessed using specific indices, based on an expert-knowledge approach, retrieved from the bibliography and combined with the intensity indicators calculated for the landscape components under investigation. This method enabled a large group of ES to be quantified simultaneously by means of comparable demand, supply and budget indicators. Results showed a complex organisation of pillar and transitional landscapes along the identified urban-rural-natural gradient, which match different bundles of ES demand and supply. The research findings contribute to a new interpretation of ES demand and supply on the landscape scale and can support a better spatial contextualisation of the ecological and socio-economic issues characterising landscape gradients.

Key words: urban-rural gradient, landscape fringes, transitional landscapes, kernel density estimation, ecosystem services

INTRODUCTION

The landscape has usually been considered as an arrangement of relatively homogeneous patches (vegetation communities, forest types, land covers) which are repeated across the space (Forman, 1995). Land-use and land-cover (LULC) have largely been used as indicators of environmental condition and landscape quality. Numerous studies point out land uses as determinant of the state of the natural environment and suggest that relationships between land use and the environment have to be understood in the wider socio-ecological context and on the landscape scale (Potschin, 2009). Anthropogenic gradients generated by the increasing intensity of LULC were defined by Forman and Godron (1986) as the specific succession in the space of natural–managed–cultivated–suburban–urban landscapes. This view implies the identification of fringe regions or transitional landscapes, where different pressures due to human activities arise, causing more or less marked, unstable conditions involving both the internal configuration and the relationships with the surroundings (Cavailhès et al., 2004; Valentini, 2006). These pressures affect the supply of functions and services expected from the ecosystems of these areas.

Since the Millennium Ecosystem Assessment (2005), many scientists are directing their efforts to studying and quantifying ecosystems goods and services (ES), defined as the benefits people obtain from ecosystems. ES have recently become a primary objective in ecology conservation research, as a framework supporting decisions in natural resource management (Wallace, 2007). The concept of ES integrates the ecological perspective and the anthropological viewpoint to analyse the ecosystem functions (carried out by ecosystem components and processes) according to how useful it is perceived (Burkhard et al., 2012; de Groot et al., 2010; Haines-Young & Potschin, 2012). Different approaches to assess and map ecosystem services on the landscape scale have been developed and applied at different spatial scales by several authors (see e.g. Costanza et al., 1997; Fisher et al., 2008; Naidoo et al. 2008, Gimona & van der Horst, 2007, Burkhard et al., 2010). However, special attention has recently been paid to approaches based on LULC and expert knowledge with the aim of introducing the ES concept to decision makers and land managers as a tool to support sustainable landscape planning. In the framework of ES

mapping methods, the use of proxy indicators to assess the potential ES supply offered by LULC can be viewed as a proper solution to overcome the difficulty of systematically considering a wide, complex set of ES within landscape management and land-use planning processes (Bastian et al., 2012; Burkhard et al., 2009; Vizzari & Sigura, 2013).

Human decisions and related actions, such as land cover change and land use development, dramatically affect both the ES demand and supply. In fact, ES are a result of the availability and integrity of ecosystems in a certain area. However, they are recognised as real services on the basis of the human benefit received by the people living in that area. Along landscape gradients, generated by the intensity of human use of land, different mosaics of LULC and different characteristics of landscape structural elements (patches) have been identified (Sigura et al., 2010; Vizzari 2011b; Modica et al., 2012; Vizzari and Sigura, 2013, Gentili et al., 2014). Thus, especially in transitional landscapes of fringe areas (e.g. urban-rural landscapes, rural-natural landscapes), a different demand and supply of ES can be expected, on the basis of such structural dissimilarities and peculiarities.

In this context, the following aims were defined for this research:

1. The identification and characterisation of the types of landscape along a gradient of LULC intensity;
2. An analysis of the potential ES demand, supply and budget within the types of landscape expressed along the landscape gradient.

The methodological approach, tested in a rural landscape of central Italy and presented in this paper, can be useful to perform a detailed classification of the landscape gradient and to characterise the related supply, demand, and budget of ES. These results can effectively support landscape planning and management on a municipal and supra-municipal level.

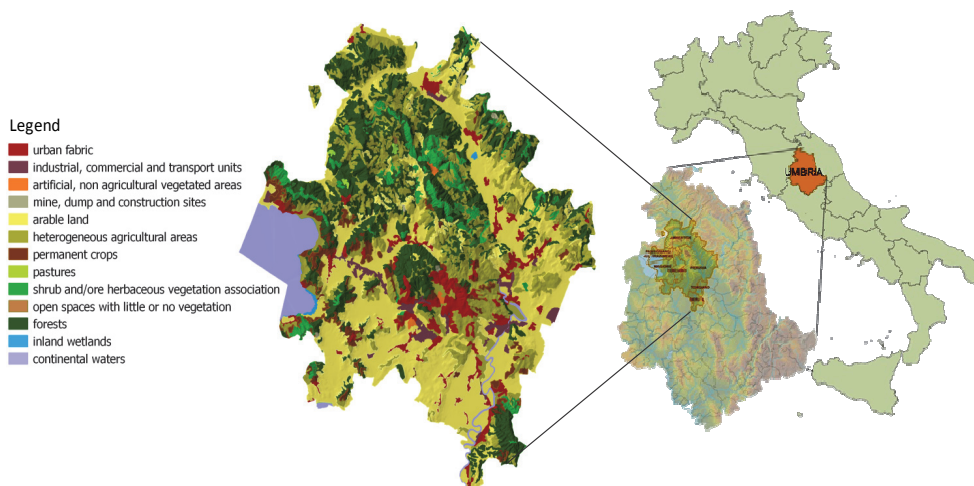


Fig. 1 Location and LULC (from Corine 2006) of the study area

Study area

The study area, approximately 1007 km² wide, is located in the Region of Umbria and includes the city of Perugia (Italy) and its surroundings. It comprises seven different municipalities: Perugia, Magione, Passignano sul Trasimeno, Corciano, Umbertide, Torgiano and Deruta (Fig. 1).

The area is characterised by a very typical landscape of central Italy, consisting of 58% agricultural land, 28% forests and semi-natural areas, 8% built-up areas and less than 6% wetlands and water bodies (Corine Land Cover 2006, personal elaboration). The area encompasses an urban and productive tissue of high territorial complexity around the city of Perugia, characterised during recent decades by a high rate of urbanisation and the relevant rural transformations, which have led to a general intensification of agricultural land uses.

METHODS

Three main steps were identified: (a) spatial modelling of gradients generated by key landscape components; (b) multivariate spatial analysis and landscape classification; (c) assessment and mapping of potential ES demand, supply and budget.

Table 1 Landscape features and related intensity indicators used in the gradient modeling and subsequent ordination of the types of landscape.

Key landscape components	Landscape features - LULC	Intensity indicators	KDE derived indicators
Urbanisation	Predominantly residential buildings	Total covered area (covered area*number of floors)	RBI, Residential Building Intensity
	Commercial buildings		CBI, Commercial Building Intensity
	Roads	Road width	RDI, Road Intensity
Agriculture	Olive groves	Number of trees	OGI, Olive Grove Intensity
	Vineyards	Crop area	VGI, Vineyard Intensity
	Arable land	Crop area	ALI, Arable Land Intensity
Natural elements	Forests and other non-agricultural permanent vegetation	NDVI (>0.65)	FRI, Forest Intensity

The model for landscape gradient detection and analysis was based on the calculation of continuous intensity indicators, associated with urbanisation, agriculture and natural elements, considered as key components of the landscape gradient configuration. The assumption was based on proposals by Naveh and Lieberman (1984) and Wolfgang Haber (1990) to order the types of landscapes. These proposals consider the degree of

modification or replacement of natural bio-ecosystems vs the degree of the dominance of man-made artefacts and the degree of human influence vs the ability of the ecosystem to self-regulate. Table 1 shows the key landscape gradient features and their related intensity indicators used for gradient analysis.

The agricultural land uses were studied by separating the three dominant crops in the area: arable crops, olive groves and vineyards. The spatial distribution of arable crops and vineyards were obtained from the Common Agricultural Policy (CAP) regional database (2010) linked with the geo-referenced centroids of the cadastral parcels. The use of the parcel centroids rather than the polygons helped solve the problems related to multiple correspondences between CAP and cadastral data due to the presence of sub-parcels under different crops. The data source for the spatial distribution of the olive groves was the national olive trees inventory.

The urban features of layers of predominantly residential and commercial building were structured by extracting the geo-referenced centroids of all the buildings in the study area, retrieved from a regional cadastral database (Regione Umbria). The road network layer was retrieved from another, highly detailed, regional, spatial database (Regione Umbria). The Landsat 5 TM NDVI data (May 2007) was used to identify the areas covered by forest, selecting those areas covered by index values greater than 0.65. This threshold was calculated by collecting test data in the study area in order to select only the forest and other non-agricultural, permanent vegetation land cover.

Density analysis was chosen from among the various gridding techniques to transform values measured at specific locations in continuous surfaces and to model the spatial distribution for the considered variable (Bailey and Gatrell, 1995). The Kernel Density Estimation (KDE) technique was then applied to calculate the continuous intensity indicators associated with urbanisation, agriculture and natural elements (Table 1). KDE produces smoother surfaces, useful for representing landscape gradients (Vizzari, 2011a) by applying a moving window superimposed over a grid of locations, in which the density of events is estimated at each location according to a kernel function. The degree of smoothing is controlled by the kernel bandwidth (Gatrell et al., 1996). After testing four different values (250, 500, 750, 1000 m) (Bailey and Gatrell, 1995, Lloyd, 2007, Vizzari, 2011a, Modica et al., 2012), the quartic function, a simplification of the Gaussian function (Gatrell et al., 1996; Levine, 2004, 2006), with a bandwidth of 500 m, was finally chosen. The cell size for the KDE layers was set at 50 m, according to the scale of analysis (Hengl, 2006).

The resulting KDE layers were analysed by means of a PCA (Principal Component Analysis) to reduce variability due to correlation between the indicators. The resulting seven PCs (expressing 100% of the original variance) were processed by an ISODATA cluster analysis (Iterative Self-Organising Data Analysis Technique; Ball and Hall, 1965; Richards, 1999) to obtain the final order of the types of landscape.

In order to understand the potential ES capacity, demand and supply for each landscape type, the habitat focus approach, developed by Burkhard et al. (2010 and 2012) and Jacobs et al. (2014), was adopted. This approach is based on matrices, compiled by experts, which estimate the ES demand and supply for each LULC class. The supply matrix expresses the different LULC abilities to provide selected ecosystem goods and services, whereas the demand matrix expresses the requirements of ecosystem services for humans living off the

different LULC classes. Both demand and supply are assessed by a weight (P) between 0 and 5, which makes all the demand and supply values directly comparable. For each landscape area, ES demands and supplies were calculated using the following equation:

$$ES_j = \sum_i P_{ij} I_i$$

where P is the weight of the j -th ES demand or supply related to i -th LULC and I is the averaged value of the normalised intensity indicator of the i -th LULC composing the landscape of each area. The budget of each ES in each area was then calculated using the following equation:

$$ES \text{ budget} = ES \text{ supply} - ES \text{ demand}$$

RESULTS AND DISCUSSION

Eleven landscape types were identified by the ISODATA cluster analysis, the spatial distribution of which within the study area is represented in Fig. 2 and summarised in Table 2. Average values of intensity indicators enabled the identification of so-called “pillar” and “transitional” landscapes (Fig. 3) distinguished by the relative prevalence of a LULC intensity to be identified. Prevalence was detected by comparing the local average response of each indicator with the corresponding mean value observed along the gradient. As expected, the trends of distribution of pillar landscapes show natural responses linked mainly with the steeper areas and urban landscapes with the major towns of the area, whereas agricultural landscapes appear more widely spread over the area. On the contrary, transitional landscapes assume a more complex, heterogeneous configuration among the more compact pillar landscapes. As a consequence, different, variegated landscape sequences can be detected along specific transects of analysis.

For each landscape area, the supply of a total of 26 ES (including 7 supporting ES) and the demand and budget of 19 ES were calculated. For example purposes, the demand, supply, and budget maps for three ES (crop provisioning, groundwater recharge, and recreational and aesthetic values) are presented in this paper (Fig. 4). In the first case, the southern and eastern part of the study area are those which are able to provide a higher level of this ES, whereas the most demanding areas are those with a higher population, which is clearly concentrated in the urban areas. As expected, the budget is negative in the urban areas, where demand is higher than the supply, and is positive in the majority of plain, rural landscapes, where supply is higher than the demand. The groundwater recharge service is supplied mainly by forests and permeable surfaces (e.g. cultivated areas). However, the main demand comes not only from within areas with a higher intensity of urban elements (urban and commercial buildings and roads), but also from agricultural areas, which may require groundwater for irrigation. The recreational and aesthetic services are mostly supplied by natural areas, although they are in highest demand by the urban areas. Contrary to the previous case, there is actually no demand for recreational and aesthetic services within the agricultural areas, where the ES demand is generally related to crop production.

In the areas where the budget is approximately 0, excluding situations of very low or absent demand, the landscape denotes a mixed composition with the coexistence of high values of demand and supply for the ES under investigation. This is a very important issue when the ES under investigation cannot be easily delivered far from its place of production or, more generally, when the transport of such ES, even if it were possible, generates costs.

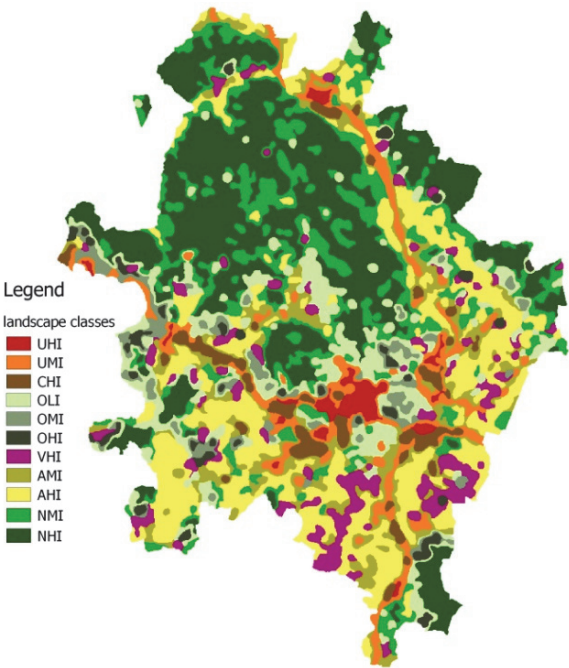


Fig. 2 Map of the landscape classes identified by cluster analysis.

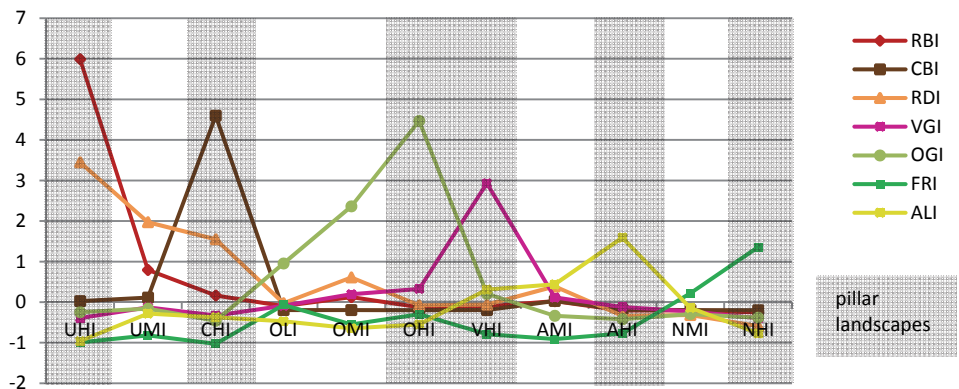


Fig. 3 Average standardised intensity indicators within the landscape classes.

Table 2 Codes, names, and brief descriptions of landscape classes.

Code	Name	Description
UHI	Urban High Intensity	Landscapes dominated by residential buildings.
UMI	Urban Medium Intensity	Landscapes dominated by roads, influenced by urban buildings mixed with agricultural and natural elements.
CHI	Commercial High Intensity	Landscapes dominated by industrial or commercial buildings, with a relatively high influence by roads.
OLI	Olive groves Low Intensity	Landscapes characterised by a relatively high intensity of olive groves and natural elements.
OMI	Olive groves Medium Intensity	Landscapes dominated by olive groves, with a relatively high intensity of roads, urban elements and vineyards.
OHI	Olive groves High Intensity	Landscapes strongly dominated by olive groves.
VHI	Vineyards High Intensity	Landscapes dominated by vineyards, with a relatively high influence of arable lands and olive groves.
AMI	Agriculture Medium Intensity	Landscapes characterised by a relatively high intensity of agricultural elements and by the coexistence of urban and varying agricultural features.
AHI	Agriculture High Intensity	Landscapes dominated by arable crops.
NMI	Natural Medium Intensity	Landscapes dominated by natural elements with the coexistence of urban and agricultural elements.
NHI	Natural High Intensity	Landscapes dominated by natural forests, with a low influence of urban features.

CONCLUSIONS

This study can contribute to identifying the need to focus on the composition and spatial configuration of the entire urban-rural-natural gradient expressed by landscapes, in order to obtain integrated information supporting decisions regarding the arrangement, intensity and functionality of land uses. To this aim, KDE techniques and multivariate analysis to model and classify the types of landscape along such gradient demonstrated their applicability, even when beginning from extremely different data sources regarding urban, agriculture and natural features.

The assessment of the ES demand, supply, and budget, even though based on a simplified approach, can represent a first attempt to overcome the difficulties related to the comparison and integrated analysis of numerous, different services and functions. Such an analysis along the gradient can be very relevant to analyse and plan the landscape more effectively. The approach could be improved by means of a more detailed and effective ES selection and by the calculation of the related weights e.g. using multicriteria methods (Kosche et al. 2012), which takes into account the specific landscape and LULC characteristics of the study area. Moreover, land use intensity indicators, used as scores in

the ES calculation, could also be improved by selecting a wider set of more reliable factors to determine the potential demand, supply, and budget of ecosystem services.

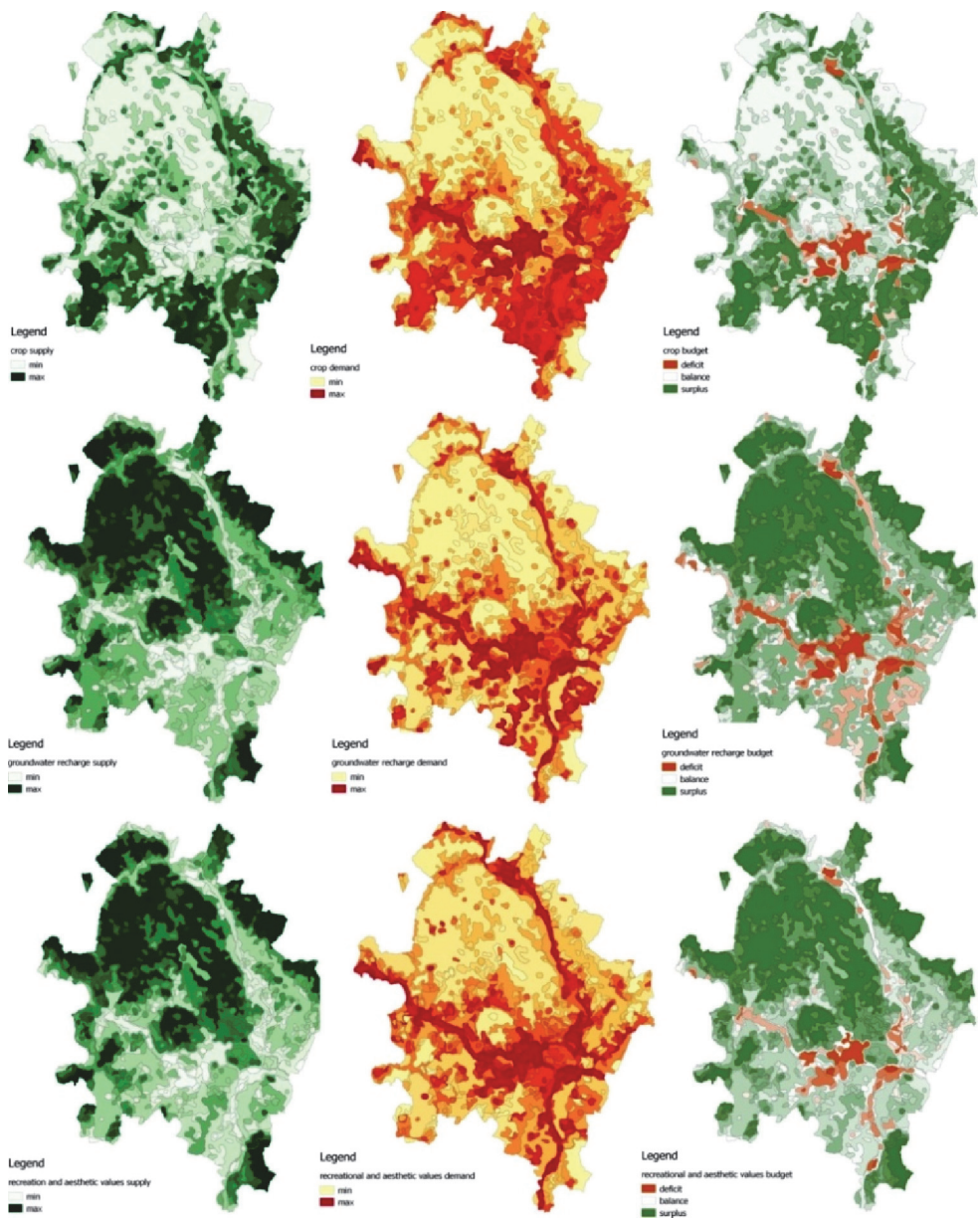


Fig. 4 Demand, supply and budget maps of the three ES samples

ACKNOWLEDGEMENTS

This research was developed within the framework of the TRUSTEE (Towards Rural Synergies and Trade-offs between Economic development and Ecosystem services) project, funded by the RURAGRI ERA-NET Consortium, including the Italian Ministry of Agricultural, Food, and Forestry Policies.

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ENERGY SIMULATION MODEL OF AGROECOSYSTEM – CASE STUDY OF ANIMAL BREEDING FARM

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ABSTRACT

The process of simulation in the environment-economy systems, such as the agro-ecosystems, mainly uses the logical models as a bases of trying to copy the dynamic of the real situation from the system, for example from an animal breeding farm integrated in the natural environment. This is done aiming to preview the effective behaviour. The proposed simulating model has the form of a logical flow diagram describes the interdependence of the logical relation between variables. The paper proposes itself to find the optimum variant through the energetic transformations in agro-ecosystems by decomposing and analysing the composing subsystems. The objective is to put into evidence the quantitative and qualitative influence of the values of inputs upon the outputs, respectively, resulting biomass (i.e. agro-food products) energetically expressed. Using the possibilities offered by the MATLAB/SIMULINK software system one can deduce a series of observations and conclusions which allow appreciating the degree of sustainability of the evolution of the agro-ecosystems and of the economic units integrated in them.

Key words: agro-ecosystem, flow diagram, emergy, sustainability

INTRODUCTION

The process of simulation in the environment-economy systems, such as the agro-ecosystems, mainly uses the logical models as a bases of trying to copy the dynamic of the real situation of the system, for example an animal breeding farm. Simulation gives the possibility to assess the most likely effects of the various decisions under the frame of the environment – economy system (EES). Thereby all negative consequences can be avoided and can be introduced more efficient methods, with reference to feed-back and feed-before

mechanisms, as adjusted cybernetic elements in the process of integrated management [Armstrong, M., 200, Ackott, R.L. Gruia, R., 1986,].

The systems with environment-economy interface, being in fact anthropized ecosystems, may be transformed in view to the sustainable development. We mean to adjust the economic development to the ecologic bearability. In this context, the goods and the services of the environment, the output of the processing of the resources, together with the influence of the market demands are the elements of the economy remodeling. All this may be synthetically expressed by certain parameters which may have as a result the help in taking decisions in piloting (the management) the EES.

The main objective of the simulation is to offer the possibility to calculate the amount of the resources necessary to obtain a certain behaviour of the EES, with a specific level of the inputs.

METHOD

As a basis of study in the elaboration of the parameters was used the emergetic analysis method (the eco-energetic method) which was offering the advantage of a unitary, synthetically and systemic expression (Odum, 1983, 1984, Gruia, R., 1986.) We must note that the first stage of the method is extremely laborious, including energetic diagrams and calculations emergetically expressed of the system flows and of its components. The second stage of the method is based on the three major flows of input and output from the system expressed as emergetic sums (noted in the accepted model of interface as I^+ and F^+ – the inputs and respectively Y^- – the outputs).

Based on this, the table 1 shows the main emergetic parameters of sustainable development of the environment-economy systems (EES).

Table 1 The emergetic parameters of sustainable development of the environment-economy systems (EES)

Nr.	Parameter	U.M.	Calculation equation	Observations
1	The degree of concentration of the energy	J/J effective	Solar energy (type A) Energy from syst. (Type B)	It shows the degree of concentration of the energy in every point of the system by the number of joules energy type A incorporated in a unity of B type.
2	System emergy, or emergy of C type (C^{emJ})	emJ	$EpJ \cdot Tr^{emJ/J}$	The eco-energetic unity of measure, it is capable to measure the action of the available energy in a period of time (ex. 1 year). EpJ = effective energy measured in the System. Tr = solar transformity, or “transformation – conversion” of the solar energy: the quantity of solar energy necessary to introduce a unity (1 joule) from a certain good.

3	The real work (ρ)	EmJ	$F^+ + I^+$	The eMergetic sum of human labour (F^+ flood) and the environmental work (I^+ flood).
4	The energy externality (xE)	EmJ/year	$\frac{I^+}{I^+ + F^+}$	The external gain of order of the EEs by the free environment used, evaluation taking into account the environment externality (I^+) repre-sented by the non-price goods and services of the environment (low quality energy), as well as the eco-nomic externalities (F^+) represen-ted by the goods and services bought on the market (high quality energy).
5	The efficacy of EEs (e)	Nr. ($e < 1$)	$\frac{Y^-}{F^+ + I^+}$ or $\frac{Y^-}{\rho}$	The efficiency of the system expressed by the relation between the useful eMergy of the incomes got by the outputs from the system (Y^-) and the eMergy spent by the inputs as an environment system and from the market.
6	The intensity of the purchase of the goods from the market or the eMergy (i_ρ)	EmJ or emJ/ha	$\frac{Y^-}{F^+}$	It shows the level of the inputs in the system as a contribution through the environmental work with the realized production.
7	The intensity of the environmental work (i_m)	EmJ or emJ/ha	$\frac{Y^-}{I^+}$	It shows the level of the inputs in the system as a contribution through the environmental work with the realized production.
8	The intensity of the production support through the environmental work (i_ω)	EmJ or emJ/ha	$\frac{I^+}{Y^-}$	It shows in principle the support by the environment of the economic sphere (of the outputs), representing a calculation element for the objective evaluation of the sustainability.
9	The draining coefficient (D)	%	$100 e^2$	It shows the relation from the environment externalities “digested” in order to equilibrate the environment-economy discords; it is the combustion element to start and sustain the draining from the environment towards the economic subsystem.

The simulation process consists in the use of the theoretical model (flow chart, shown in figure 1), in order to highlight the real behaviour of the system. By modifying one or more input sizes respecting laws described by linear mathematical functions (right variation or with a certain downhill) or non-linear ones (sinusoidal, tangential), can be underlined the dynamic function of the real system. [Bebeselea, A. et al., 2011],

Figure 1 The simulation model of an agroecosystem (which include a farm with carnivorous species) variable parameter: Environment externalities I[†].

The obtained information from the flow chart was utilised through the determinist simulation technique, using MATLAB/SIMULINK application.

This simulation, used under the frame of the given system, has the possibility to point out needed decisions for the exact calculation of the resources necessary to obtain a certain result pre-established with a certain level of the inputs. The purpose is to rule out the present uncertainties in the farm during every day life for the sake of convenience and routine.

RESULTS AND DISCUSSION

The present paper is based on a flow chart [Duckworth, W.E. și col., 1977, Gruia, R., 1986] made after a case study, quantified through the eco-energetic (emergetic) analyses method, done in a carnivorous animal breeding farm (rainbow trout and fur animals: minks, polecat and polar foxes) with an average effective of 12000 fur animals and 200000 trout, with an average biomass of approximately 46 t, with a habitat surface of approximately 10 ha, at an altitude of 560 m, agro-ecological conditions specific to the temperate zone. The respective case study has structured the energetic diagram of the farm, with the help of which, through the solar transformity and the existing energy in each point of the system it has calculated the emergetic contribution of the environment externalities, of the financial flow introduced by man through the economic activity and the market influence trough buying and selling, aiming to satisfy the population demands [Gruia, R., 1986], [Slavici, T., 2013].

From the flow chart can observe the fact that the inputs are structured on groups, in which are highlighted the composing elements. Are also mentioned the outputs and losses, as well as the main piloting parameters of the system. Under the presented conditions, the simulation is suggested as a work manner to study the variable interdependence and the possible results.

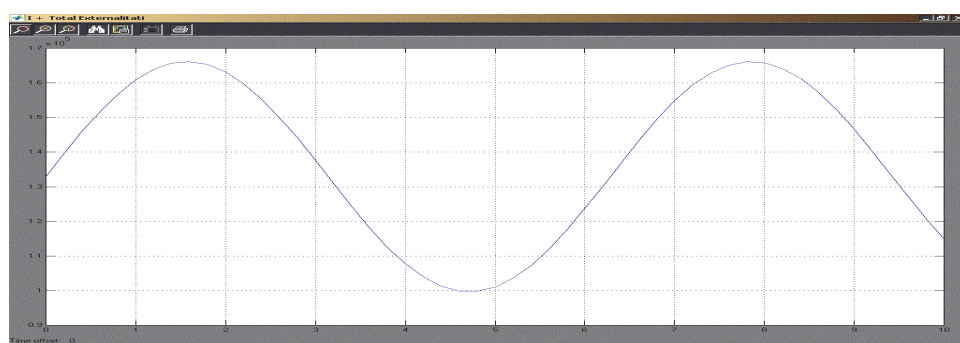


Figure 2 The evolution in time of the environment contribution

The first simulation analyses the situation in which is considered to be most often met in the productive activity, namely the one linked to the variation of the environment externalities, under the conditions when the economy contribution (the human activity) and

the market influence are assumed to be constant. For a suitable analyses of the environment variation effects on other specific followed parameters, it was used a sinusoid in time function (to express the environment externalities), with an amplitude of $\pm 25\%$ face to the average value of the environment contribution (132937, 3 E13 emJ/year). Consequently to the application of the simulating program were obtained results synthesized in figure 2 to 6 and table 1.

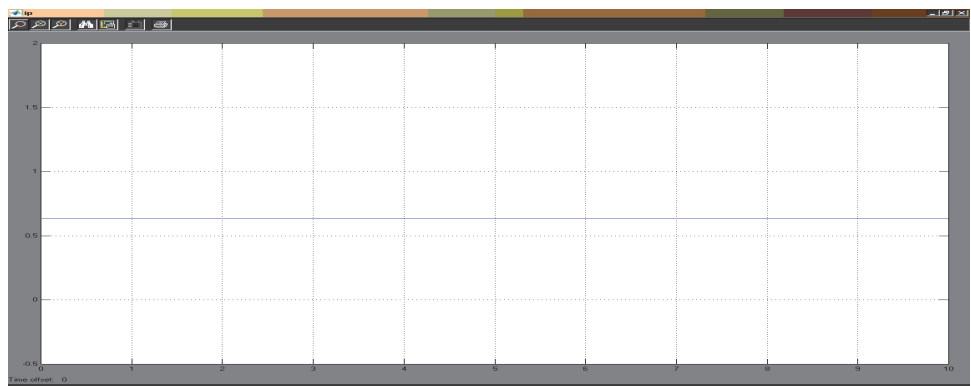


Figure 3 The evolution in time of the intensity of the goods purchased on market

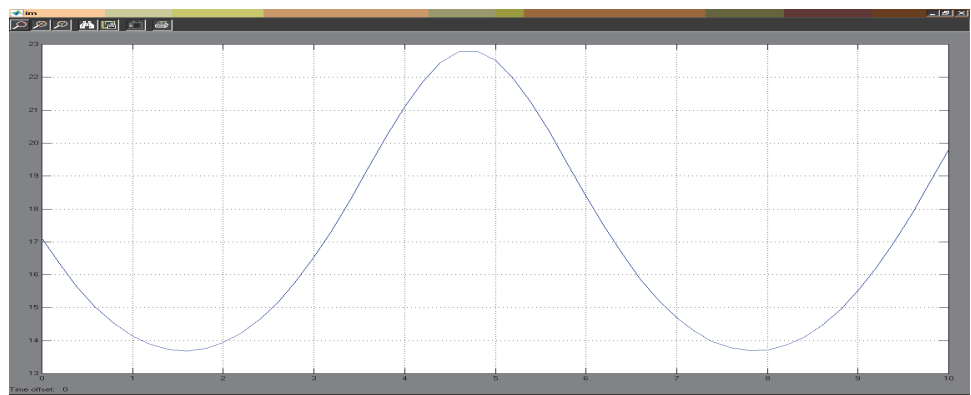


Figure 4 The evolution in time of the intensity of the utilisation of the environment work

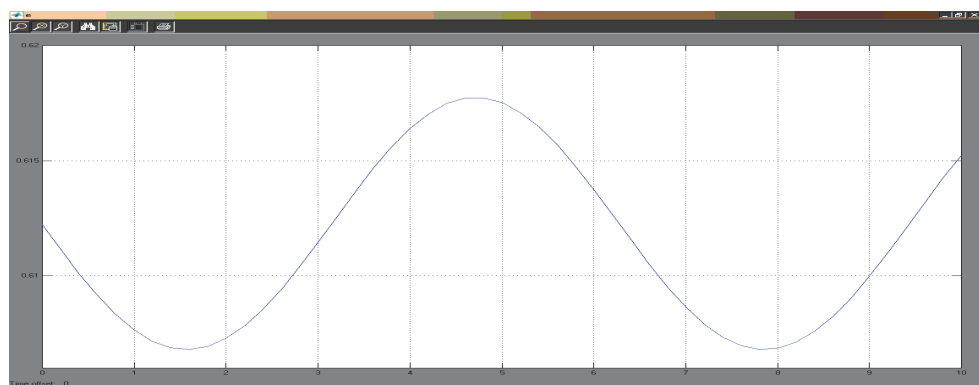


Figure 5 The evolution in time of the system efficiency coefficient

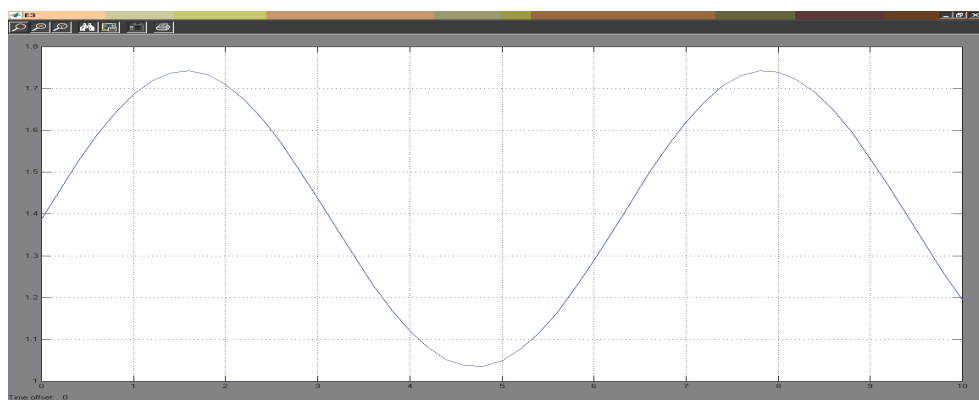


Figure 6 The evolution in time of the sustainability coefficient

Table 2 Estimation of the effects of the non-price contribution variation of the environment introduced in EES through utilized simulating variants

Specification	Intensity of the goods purchased on market (i_p)	Intensity of the environment work utilisation (i_m)	System efficiency coefficient (e)	System sustainability coefficient (E^3)
Environment externality variation with + 0...25 %	Uniform	- 0...3,5 %	- 0...0,5 %	+ 0...26,09 %
Environment externality variation with - 0...25 %	Uniform	+ 0...5,7 %	+ 0...0,6 %	- 0...24,64 %

Simulation results	The growth as well as the decrease of the environmental externalities DO NOT affect the output of the market purchased goods used to achieve result (production) in the given system.	The growth of the environment externalities with up to 25 % may lead to reduce the output of the utilisation of the environment work with up to 3,5 %. In exchange the diminishing of the environment externalities with up to 25 % may lead to a growth of the output of the utilisation of the environment work with up to 5,7 %.	The growth of the environment externalities with up to 25 % may lead to diminish the system efficiency with up to 0,5 %, while the diminishing of the environment contribution with up to 25% would lead to the growth of the system efficiency with up to 0,6 %.	The growth of the environment externalities with up to 25 % significantly influences the sustainability growth (with 26,1 %), while the diminishing, at the same level, has a similar effect, i.e. the sustainability diminishing (with 24,6 %), underlying the fact that the level of the utilised environment externalities expresses a sustainability about the optimum in report with the economic activity developed under the frame of the system.
Partial conclusions	The variation of the environment contribution (+/-) does not influence the expenses on market purchased goods for the production achievement.	It can be observed that a certain amount of natural capital has been uselessly spent, but which hasn't economically influenced (the environment work being non-price), but which may lead in time to the appearance of certain prejudices as for the environment protection.	The variation of the environment contribution (+/-) shows the growth or diminishing of the EES efficiency approximately at the same ratio, which shows the registered level of the environment externalities, is optimum for a farm with carnivorous species integrated in the corresponding ecosystem.	The level of the environment contribution introduced in the system has been optimum as for the sustainability, indicating an equilibrium concerning the sustaining capacity by the environment of the economic activity from the given system.

Another simulation proposed the situation in which the capital varies as sinusoidal function like in fig. 7a ($2.2 \times 10E6 \dots 3.7 \times 10E6$). In fig. 7b the sustainability coefficient can be observed with a different shape, and fig. 7c shows d. the system efficiency coefficient.

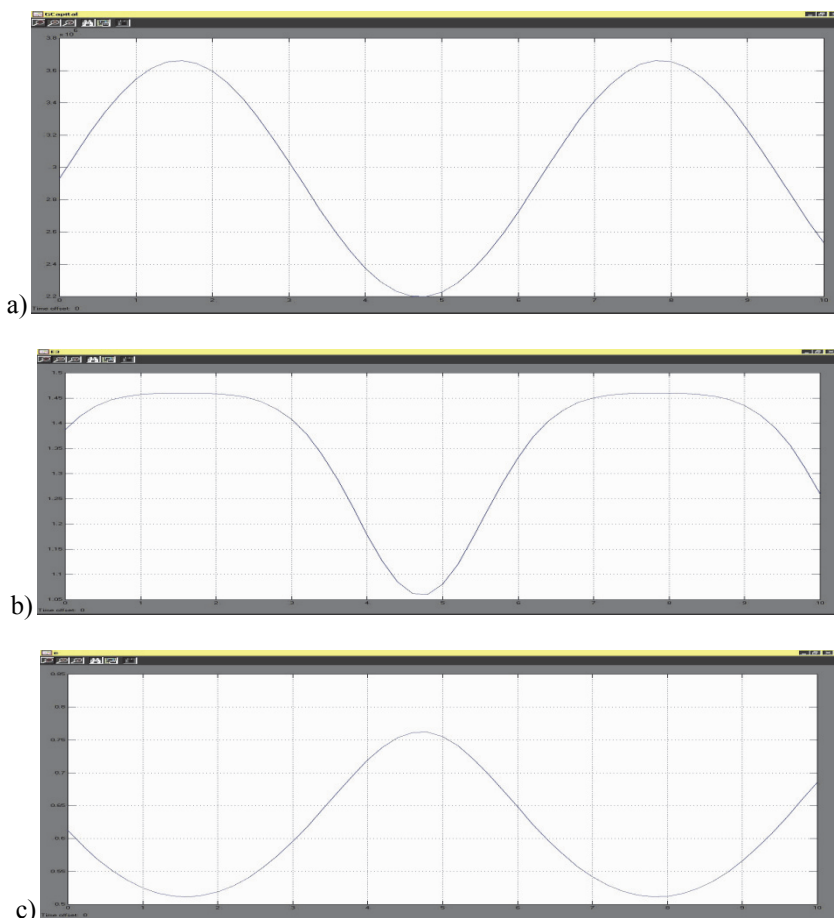


Fig. 7 The evolution in time of the specific parameters Capital, E^3 , e ,

CONCLUSIONS

The general conclusion to be drawn from what we have mentioned above is that, consequently to simulations done in the analysed EES (ecosystem with carnivorous farm) through environment externalities variation of $\pm 25\%$ the contribution of the environment used in the given system is optimum in report with the dynamic equilibrium of the system. A certain reduction of the environment externalities would have grown under a certain amount the output of utilising the environment work (up to 5%), but the aspect is non-significant taking into account the optimum sustainability level of the system, the one indicating an equilibrium concerning the sustaining capacity by the environment of the economic activity of the given system.

If the capital varies the system shows an inertial effect from the sustainable point of view, as well as the system efficiency coefficient.

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ANALYSIS OF SUSPENDING SYSTEM FOR PLANSIFTERS FROM MILLING PLANTS

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ABSTRACT

In the paper is presented the analytical calculation of the bending elastic constant for a supporting bar of plansifter, and a numerical calculation using the finite element method in the program ANSYS vers. 14.5.7, from which results the displacement and stress fields from supporting bar of a plansifter produced in Romania (SPP 420). The analytical calculation has started from theoretical model of bar stressed at bending, that consider how the gripping of the bar at both ends of its take place – one recessed and the other having blocked rotation of cross section, finally being obtained the relation which the bending elastic constant is calculated for a plansifter supporting bar. For numerical calculation, geometry of plansifter was modeled, were introduced loads and fixing conditions of plansifter and was discretized the model thus obtained. After calculation, were obtained the system displacements and tensions in suspending bars of plansifter.

The study presented may be of interest for specialists in designing and construction of plansifters on the technological flow of milling plants, thus motion of plansifter to be the predicted one.

Key words: plansifter, suspending system, bending, yield stress

INTRODUCTION AND LITERATURE REVIEW

Sifting process with plansifters is extremely complex, it being subject of research of numerous specialists worldwide. Among them, first authors who analyzed the dynamics of the sifting process and revealed factors that affects it were Jansen and Glastonbury, [3]. In 2009, KeShun Liu, [4], make a comprehensive analysis of the main factors that influence the sifting process efficiency.

Plansifters occupies a key position in the technological process of obtaining wheat flour, affecting the extraction yield and finished product quality. Throughout the time, plansifters have undergone considerable changes from the point of view of construction, thus, we can

mention: number of compartments, sifting surface, sifting frames shape, type of fabrics, fabric cleaning systems, actuation systems, suspending systems etc. Nevertheless, to ensure their high reliability, specialists in construction of milling equipments field grants an increased attention to suspending systems of plansifters.

To obtain high yields, geometric dimensions of plansifters increased considerably in the last 40 years. Sifting surfaces also increased from about 30 m² to over 90 m² on the equipment. The new models has made possible the doubling of the specific load, and the space occupied by plansifters was reduced to one third. Considering the changes suffered, suspending system of plansifters becomes increasingly important, on the one hand to ensure machine operation at parameters fixed by specialists, and on the other hand to support the entire weight of it (plansifter with grist) during operation.

From the point of view of suspending, there is suspended plansifter (the most currently used), free-oscillating plansifter and pendular plansifters, [6]. Generally, elastic supports for suspending of plansifters have length of 1.5-2.5 m and circular section, being mounted recessed on both ends (at the top on a metal frame attached to the ceiling). If initial the elastic supports of plansifters were made of boiled beech wood, bamboo or reed, today manufacturers prefer to use composite materials such as plastic material reinforced with glass fibres, [10,12]. If in the rest position of squared plansifters, supports have a vertical position, in the operating position, suspending bars are deformed at bottom with an arrow equal to the radius of motion circle of plansifter, forming with the vertical an angle α (angle measured between the vertical and tangent taken to mean fiber deformed in the middle of the clamping bar), [1].

Plansifter motion, respective of grist on the sifting process, is provided by an actuation device with unbalanced mass, and centrally positioned from those two bodies of the plansifter. According to papers [7,8], plansifters can be considered in analysis as an entire, a body connected elastic, which can have a motion with two degrees of freedom, movement that is generated by actuation device with unbalanced mass.

MATERIALS, METHODS AND PROCEDURES

For determination through analytical calculation of elastic constant of a suspension bar (k), was used the theoretical model shown in fig. 1.a, that regardless the clamping way of the bar at the two ends of its – one recessed and the other having blocked rotation of transversal section in planes (x,y) and (x,z).

Between the force that deforms the bar (F) and displacement of point in which it acts (w), there is relationship:

$$F = k \cdot w \quad (1)$$

where k is the elastic constant of the bar at bending. If is obtained the w displacement expression produces by force F , the elastic constant k can be calculated, as being ratio between them.

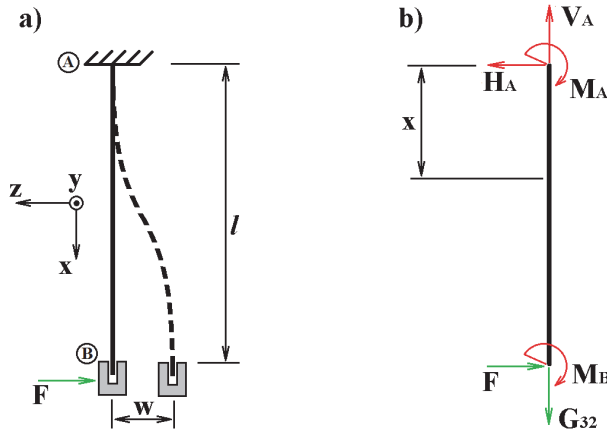


Fig. 1 a) the calculation model; b) bar loads and reactions from the bearings

Equation of deformed mean fiber of the bar is the following [2,9]:

$$\frac{d^2 w}{dx^2} = -\frac{M}{E \cdot I_y} \quad (2)$$

where w depends on the coordinate x , E is the modulus of elasticity of material from which is made the bar, I_y is the axial moment of inertia about the axis y of the bar section (for circular section of diameter d , $I_y = (\pi \cdot d^4)/64$) and M is the bending moment (this being, as well, a function of coordinate x).

For plansifter SPP 420, of Romanian construction, suspending system consists of $z=32$ de bare, diameter of a suspending bar is 12 mm, his length of 1450 mm, and for the calculation performed in this work, the material from which it is made was found to be homogeneous, with $E=10000$ MPa.

To integrate equation (2), it is necessary to know the bending moment expression. In fig. 1.b, are represented stresses acting on the bar (the bearing loads and reactions):

- F , force which produces displacement w ;
- G_{32} , force taken by one bar from those 32, from the weight of plansifter;
- M_B , moment inserted through rotation locking of section B;
- V_A , H_A și M_A , reactions introduced by blocking all degrees of freedom of section A.

Calculating the bending moment in a certain section located at a distance x from point A, chosen as the origin of the axis of the bar, is obtained:

$$M(x) = M_A - H_A \cdot x \quad (3)$$

From the equilibrium equation is obtained $H_A=F$, $V_A=G_{32}$ and $M_A = F \cdot l - M_B$. Through displacement method is determined $M_B = 0.5 \cdot F \cdot l$, [9]. Lastly, bending moment function is:

$$M(x) = 0.5 \cdot F \cdot l - F \cdot x \quad (4)$$

Substituting expression of bending moment and integrating twice the equation (2), is obtained:

$$E \cdot I_y \cdot \frac{d^2 w}{dx^2} = -F \cdot x + 0.5 \cdot F \cdot l \quad (5)$$

$$E \cdot I_y \cdot \frac{dw}{dx} = \frac{-F}{2} \cdot x^2 + 0.5 \cdot F \cdot l \cdot x + C_1 \quad (6)$$

$$E \cdot I_y \cdot w = \frac{-F}{6} \cdot x^3 + \frac{F \cdot l}{4} \cdot x^2 + C_1 \cdot x + C_2 \quad (7)$$

Integration constants C_1 and C_2 are determined from two boundary conditions:

$$w|_{x=0} = 0 \Rightarrow C_2 = 0; \quad \left. \frac{dw}{dx} \right|_{x=0} = 0 \Rightarrow C_1 = 0 \quad (8)$$

The final expression of the displacement w is the following:

$$w = \frac{F}{E \cdot I_y} \cdot \left(-\frac{x^3}{6} + \frac{l \cdot x^2}{4} \right) \quad (9)$$

For $x=l$, displacement value is:

$$w = \frac{F \cdot l^3}{12 \cdot E \cdot I_y} \quad (10)$$

Rewriting this equation as $F = k \cdot w$, is obtained:

$$F = w \cdot \frac{12 \cdot E \cdot I_y}{l^3} \quad (11)$$

from where:

$$k = \frac{12 \cdot E \cdot I_y}{l^3} \quad (12)$$

Substituting numerical, with the above values are obtained $F = 1,803 \text{ N}$.

For numerical calculation, performed using the software ANSYS v.14.5.7, was made the calculation model whose mesh is shown in fig. 2. Loads and blockages introduced in the calculation are shown in fig. 3.

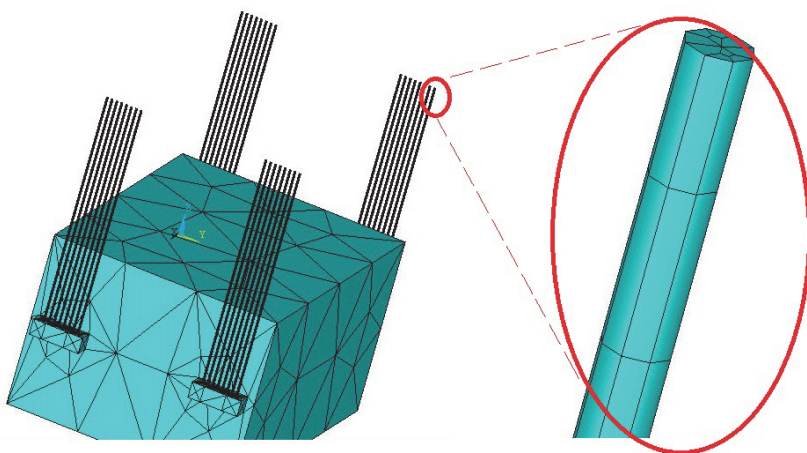


Fig. 2 Discretization of computing model

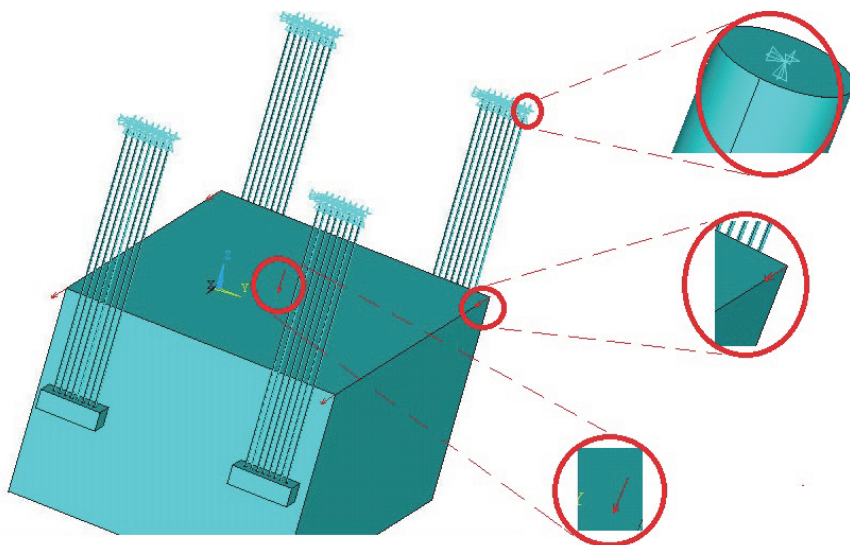


Fig. 3 Loads applied to the structure and blockages imposed

Analysis was performed in static regime, studying the behavior of one support under the action of pressure applied to the upper surface of body that shapes the plansifter, having

resultant $G = m \cdot g = 2155 \cdot 9,81 = 21141 \text{ N}$, where m is the plansifter mass with maximum load and g is the gravity acceleration. Furthermore, in the parts of the same surface, were applied four forces of value $8 \cdot F = 8 \cdot 1,803 = 14,424 \text{ N}$ (because to each applied force it corresponds eight supports). These forces must produce a horizontal displacement of plansifter of about 45 mm.

RESULTS AND DISCUSION

Under the action of plansifter weight ($M_s=1955 \text{ kg}$) and of the maximum load on the sieve ($M_i = 200 \text{ kg}$), suspending bars are stretching stressed. Stretching normal stress from the bar is calculated so:

$$\sigma_{int} = \frac{N}{A} = \frac{G_{32}}{\frac{\pi \cdot d^2}{4}} = \frac{\frac{2155 \cdot 9,81}{32}}{\frac{\pi \cdot 12^2}{4}} = 5,85 \text{ MPa}$$

where N is the axial force from the bar, equal with G_{32} , and A is the transversal section area of the bar.

Bending of bar produce, as well, a normal stress. Its maximum value is in the section A:

$$\sigma_{inc} = \frac{M_i}{W_y} = \frac{1}{2} \cdot \frac{32 \cdot F \cdot l}{\pi \cdot d^3} = \frac{16 \cdot 1,803 \cdot 1450}{\pi \cdot 12^3} = 7,71 \text{ MPa}$$

Adding the two effects, is obtained, for the maximum normal stress, the following value:

$$\sigma = \sigma_{int} + \sigma_{inc} = 13,56 \text{ MPa}$$

Neglecting the tangential stress produced by force which stresses the bar at bending, equivalent stress von Mises, calculated analytically, is 13,56 MPa.

The results of the calculation using the finite element method are presented below, as follows: in fig. 4 is given structure deformation, in fig. 5 displacement in the direction of the axis x, in fig. 6.a equivalent stress von Mises the entire structure, and in fig. 6.b von Mises stress field for a single bar.

It can be seen, comparing analytical results with those obtained numerically, that the errors are small enough. Furthermore, obtaining numerical the horizontal displacement of plansifter of about 45 mm, we can say that the finite element model is validated by analytical calculation presented in the paper.

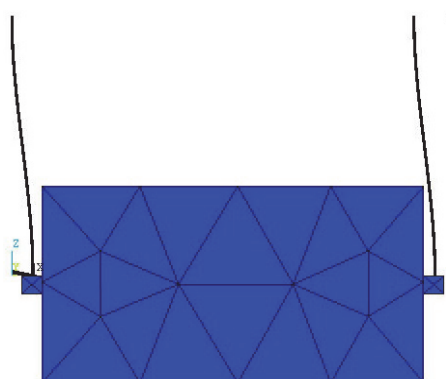


Fig. 4 Structure deformation

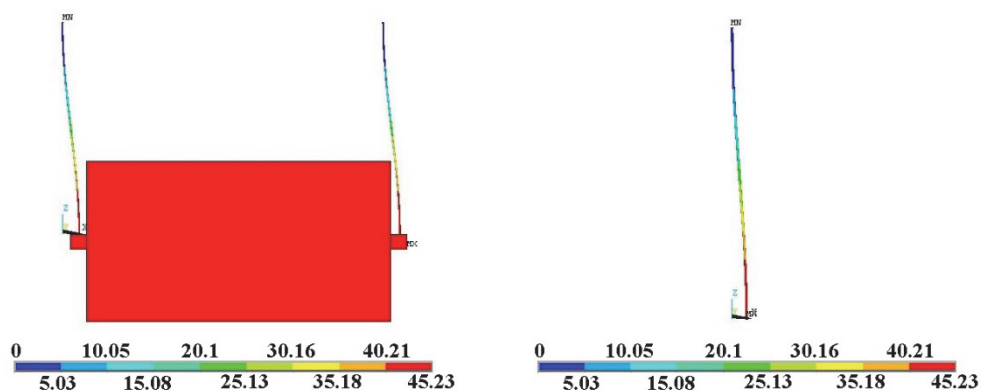


Fig. 5 Displacement fields on direction x, (mm)

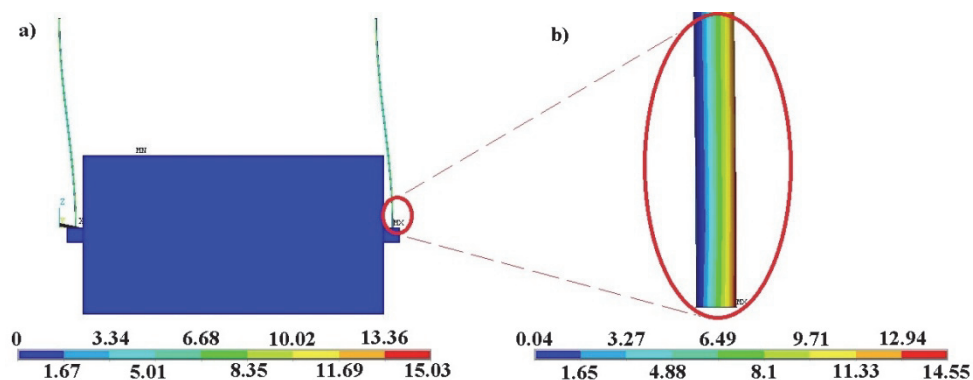


Fig. 6 a) Equivalent stress von Mises for entire structure (MPa); b) Stress field von Mises for a single bar (MPa).

In design is of interest force with which oppose the supports, by their deformation, displacement imposed to plansifter by the actuating mechanism. Thus, as the number of supports is greater, the more weight it supports one is less and the force that they oppose to plansifter displacement is greater. To calculate this force, the bending elastic constant is determined for n supports as being of n times bigger than that of one support.

In a complete rotation of plansifter, at any moment of its, stress of one support is identical, with respect to static, to that considered in the calculations performed in the paper, through bearings at the ends of the support.

CONCLUSIONS

Considering stress values obtained, may be selected for manufacturing supports a cheaper material and easy to obtain than those currently used. An example would be a plastic material natural fiber-reinforced, for which, in general, yield point exceeds 15 MPa, [5,11]

The behavior of a support and the level of its stress depends, mainly, of method of its attachment and on the material from which it is made.

As the support material is stiffer, the more tension produced by bending are higher and the force that opposes to actuating mechanism increases. Is useful as material to have a low stiffness but his fracture limit to be sufficiently high to not cede.

To eliminate this aspect, grip of supports should be through joints on both sides. Thus, their only stress would remain that produced by the plansifter weight and stress values should be diminished considerably, disappearing the component caused by bending.

Another factor that must be taken into account in designing is fatigue of supports material. If clamping would be joint-joint, this aspect is as well removed. Thus, a fatigue calculation becomes necessary to know lifetime of the supports.

AKNOWLEDGEMENT

The work has been funded by the Sectorial Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/134398.

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HARMONIC ANALYSIS OF AN VIBRATING FEEDER USING "LINEAR DYNAMICS" MODULE

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ABSTRACT

The current economic climate has completely changed the way the main companies and institutions use the simulation, in design engineering, to achieve different products. The simulation technologies compress the product development process and result in reduced costs of production, being a necessary requirement to survive in an increasingly competitive environment. In almost every industry, product development through simulation technology has become a key strategy for the development of more innovative products, reduce production costs, and accelerate time to market launch. Dynamic analysis, using the "Linear Dynamics" module in Solid Works Simulation, allows designers and engineers to quickly and efficiently determine the impact over time of variable loads on the structure of the product to ensure high performance, quality and safety.

This paper includes a harmonic analysis, static analysis of a vibrating feeder; estimation of natural frequency of vibration and dynamic harmonic analysis. The workflow to determine the natural frequencies and harmonic analysis of vibrating feeder consists in: first we check static answer, we suspect that dynamic response should be a part of multiple static response; then, we will determine the first natural frequency of vibration of the structure, preferably in the direction of loading; We will carry out an analysis of frequency and modal study to determine how many of the frequencies of the structure should be used for summation in harmonic analysis, and in the end we conduct harmonic analysis using natural frequencies selected of the respective structure and effective load during the frequency.

Key words: harmonic analysis, simulation, frequency of vibration, vibrating feeder

INTRODUCTION

In nearly every industry, driving product development through engineering simulation technology has become a key strategy to develop more innovative products, reduce development and manufacturing costs, and accelerate time to market. To calculate the natural frequencies of a structure, the excitation and response expected, it is necessary to conduct a vibration analysis. In this way we can determine whether a certain structure is capable to perform the function for which it was designed and in addition, the dynamic loads acting on a structure can be predicted, such as tensions appeared, fatigue and noises. Designers and engineers can quickly and efficiently determine the impact of time varying loads on the structural response of their product design, using dynamic analysis, to ensure performance, quality and safety. Dynamic analysis can incorporate frequency, impact, and drop tests. The primary unknown in a dynamic analysis is component displacement over time, but with this calculated, stresses, velocities, and accelerations can also be determined together with the natural modes of vibration.

With linear dynamic analysis, the loads are applied with respect to time or frequency, they can be defined in a deterministic nature (periodic or non-periodic) or non-deterministic, which means they are not precise but defined statistically. Unlike linear static analysis, where only the stiffness, displacement and loads are important, in linear dynamic system are included the damping and mass matrices in the equations of motion.

Using “Linear Dynamics” module we will conduct a harmonic analysis, estimate natural frequency of vibration and determine how many of the frequencies of the structure should be used for summation in harmonic analysis, and in the end we conduct harmonic analysis using natural frequencies selected of the respective structure and effective load during the frequency.

METHODS

For conducting the harmonic analysis, we chosen a vibrating feeder used to transport seeds to a magnetic cylinder where take place the separation of impurities. For the analysis we need the 3D model of the vibrating feeder which is shown in Figure 1. The vibrating feeder is suspended by 4 elastic elements type leaf spring, constructed of sheet metal brass with paramagnetic properties, aims to transport the seeds to magnetic cylinder and is driven by a vibrator motor as is shown below.

The workflow to determine the natural frequencies and harmonic analysis of vibrating feeder consists in: we check the static answer; we suspect that dynamic response should be a part of multiple static responses and then, we will determine the first natural frequency of vibration of the structure, preferably in the direction of loading. We supposed that the vibrating operation takes place between 42 to 48 Hz (2500 rpm to 3000 rpm), the external load is about 100 N and the weight of the system is 7, 46 kg.

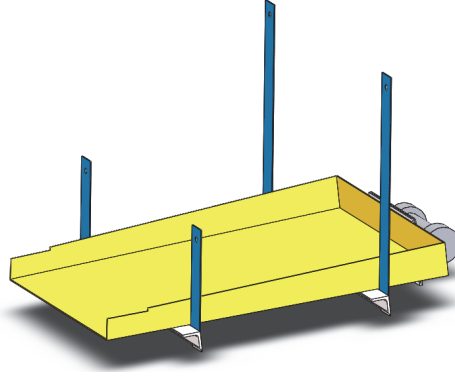


Figure 1 The 3D model of the vibrating feeder subject to the analysis

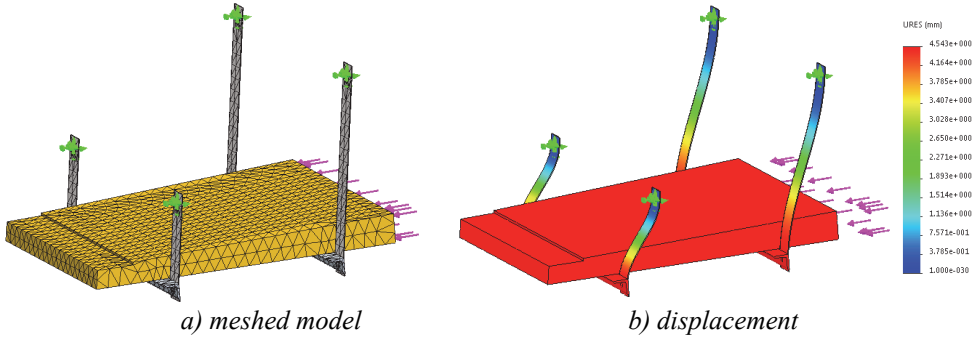


Figure 2 The static response

First we check the static response, shown in Figure 2. We see that the maximum displacement under the action of force is about 4, 54 mm. With the maximum displacement, we can calculate the characteristic frequency of the system, p , using the relation (1) [1]:

$$p = \sqrt{\frac{k}{m}} = \sqrt{\frac{g}{\delta_{st}}} \quad (1)$$

where: k is the spring constant, m is the mass of the vibrating system, δ_{st} is the maximum displacement, g is gravitational acceleration, and p is the characteristic frequency of the system.

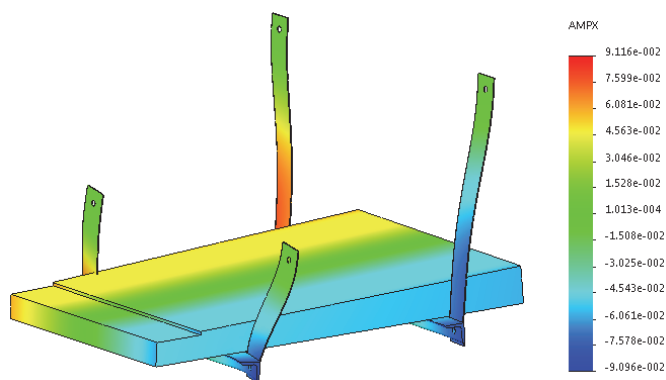
It results a frequency of $p = 46, 46$ Hz which is within the range of the dynamic loading frequency of 42 – 48 Hz we supposed. Now we know that the natural frequency should be around this value of 46, 46 Hz. We subject the vibrating system to a frequency simulation to see the natural frequencies. The resulting resonant frequencies are shown in Table 1. We selected the frequency closest to the one calculated with relation (1) and highlighted it in Table 1.

Table 1 List of resonant frequencies

Mode No.	Frequency(Rad/sec)	Frequency(Hertz)	Period(Seconds)
1	14.262	2.2699	0.44054
2	90.363	14.382	0.069533
3	268.16	42.679	0.023431
4	469.32	74.694	0.013388
5	469.69	74.754	0.013377

In frequencies analysis we can conduct a modal survey to ensure the correct including of shapes and range of frequencies that are in horizontal direction as the loading force. After viewing the all 5 mode shapes of frequencies, we select the frequency no.3 with the value of 42, 7 Hz, shown in Table 1 that contributes to the response. It is preferable to add one mode after this and use the first 4 natural frequencies for the harmonic analysis.

Among others, in frequency analysis we can run frequency study with 5 modes; survey frequencies and mode shapes for inclusion in dynamic study and provide a check on hand calculation.

**Figure 3** Frequencies model no. 3

RESULTS AND DISCUSSION

Now, we can proceed with the harmonic analysis in “Linear Dynamics”. For the result to be accurate we need to specify the modal damping at 0, 02 (steel structures, blended material and structural modal damping: percent of critical damping used ranges between 2% and 20% [6]). After we specify the loading, we are setting the limits between 40 to 50 Hz for the response graph so that the vibrating operation takes place between these limits. After we run the analysis we need that the mass participation for the loading direction (X direction) should be at least 80% mass participation. We see in Table 2 that the mass participation is 98%, which means that the analysis is accurate.

Table 2 List of mass participation

Mode No.	Freq (Hertz)	X direction	Y direction	Z direction
1	2.2699	0.98321	0.014868	1.31E-09
2	14.382	3.33E-10	5.86E-09	0.36407
3	42.679	3.13E-11	7.22E-08	0.63347
4	74.694	0.0003439	8.14E-06	7.94E-06
		Sum X = 0.98356	Sum Y = 0.014876	Sum Z = 0.99754

Because the program uses a network of nodes to perform the analysis (the network of nodes is directly proportional with the structure of the system – if the structure is bigger so is the network nodes) we use, for finding the response graph, a point as shown in Figure 5. We positioned the point near to the vibratory motor and the elastic element, where we think that the maximum displacement occurs. The response graph, shown in Figure 4, is a vertical peak amplitude displacement that shows the amplitude of up and down vibration. At a 42, 2 Hz frequency, the amplitude is about 0, 0132 mm.

In static analysis, the maximum displacement was about 4, 54 mm, so the auto balance load at this damping value and frequency reduce the displacement form 4, 54 mm to 0, 0132 mm, which means that the vibrations of the structure of the system are amortized, in time, through its structure.

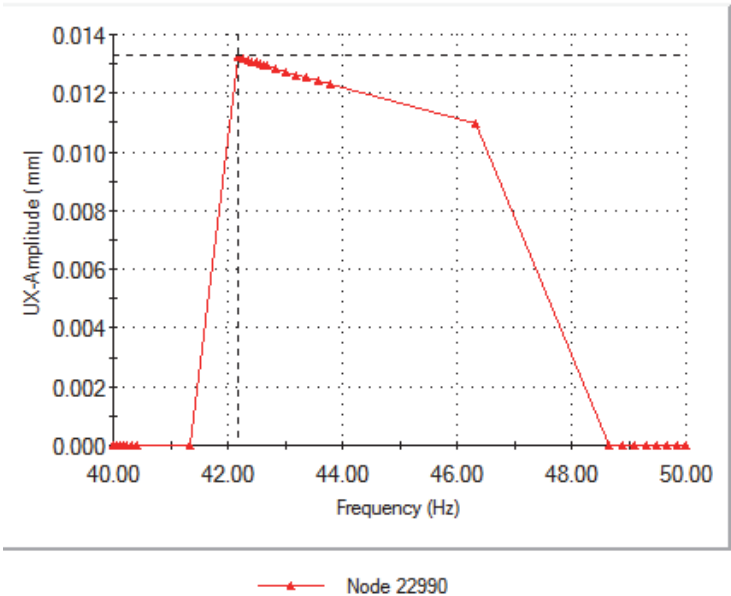


Figure 4 The response graph

We can develop a resultant displacement plot to show the deflection that alters the structure, represented in Figure 5.

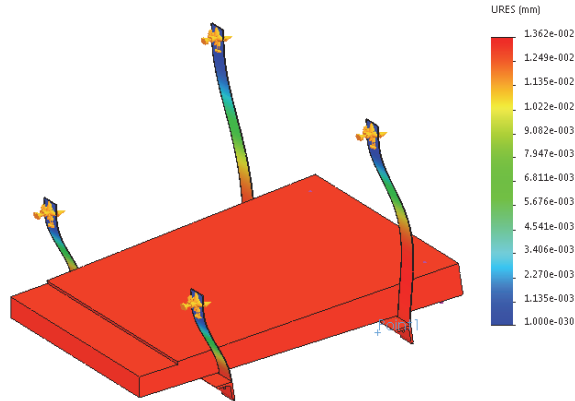


Figure 5 The resultant displacement plot

The effects of vibrations, which are simply time-varying, as seen in Figure 5, not greatly alter the structure of the system, the maximum displacements of the feeder are not very high, but over time, the vibration loads can excite dynamic responses in a structure resulting in high dynamic stresses.

CONCLUSIONS

Solid Works Simulation gives a powerful virtual testing environment for sophisticated simulation, so the designers can answer engineering challenges with complex load scenarios and multi-physics solutions, and can easily modify and analyze the approved drawing for the product.

Linear modal analysis determines the natural modes of vibration and then the displacements, stresses, strains, velocities, and accelerations. Vibration analysis is an important consideration when an applied load is not constant (static), inducing unstable modes of vibration (resonance) which result in a shortened service life and cause unexpected failures.

Understanding the natural frequency is important in predicting possible failure modes or the types of analysis required to best understand performance. Every design has its preferred frequencies of vibration, called resonant frequencies, and each such frequency is characterized by a specific shape (or mode) of vibration.

In this paper we show that the “Linear Dynamic” module is a strong and important instrument in analyzing the behavior of a structure (in this case a vibrating feeder) in time and subject to different loads; and can determine the natural frequency of the structure and then find out if the structure can perform the requirements of the work environment.

A recommended workflow for harmonic analysis in Solid Works Simulation is as follows: first we check the static response of the structure; from the static response we estimate the first natural vibration frequency; then we conduct a frequency analysis and modal survey to determine how many of the structure frequencies should be used for summation in the harmonic analysis and, in the end, we conduct the harmonic analysis using selected structure natural frequencies and the actual loading over the frequency span.

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AN OIL EXPRESSION PROCESS USING SCREW PRESSES WITH STRAINERS OIL OUTLET

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SUMMARY

The oil expression from oilseeds can be achieved by screw presses or hydraulic presses. The screw presses can be manufactured as press with single pressing chamber or press with two pressing chamber. Also, another difference at the screw presses is represented by the oil outlet which can be in form of strainers or in form of holes. The oil outlet can be disposed along the length of the pressing chamber or on the last part of it. At the same time, the discharge of the cake can be realized through a single or more nozzles which are disposed at the end of the screw and pressing chamber, in the center or circular arranged. This paper presents the study of oil expression process using a screw presses which have the pressing chamber with oil outlet of strainer type and more nozzles for cake discharge. The seeds subjected to pressing for the experiments were represented by rapeseeds. It has been determined the variation of expressed oil amount along the pressing chamber for three opening position of the feeding flap (three feed rates) and for three dimensions of the nozzles of cake outlet. The obtained results are presented in the paper together with the variation of expressed oil amount from each of the five sections of the pressing chamber (five oil drainage sections). It was found that in the first section of the pressing chamber (near the feeding area), the oil yield was null, instead it increases cumulatively towards the cake discharge area, having values between 30.9 to 32.7% for nozzles with dimension of ϕ 6.8 mm and between 36.7 to 38.4% for nozzles of ϕ 5.2 mm. Also, it was obtained by computer regression the equation of oil yield variation (in %) along the pressing chamber and its coefficients based on an exponential distribution law. The results may be helpful for screw presses designers and manufacturers, as well as for their users.

Key words: screw press, strainers, pressing section, nozzles, feed rate, regression, oil yield.

INTRODUCTION

Oil products industry produces edible and inedible oils. About 2/3 of total oil products are the edible oils, which are used directly in foods or in the manufacture of margarine, mayonnaise, bakery and pastry products, cooking fats, preserves etc. The remaining 1/3 of the total volume of produced oil are the technical oils, used in the production of various products, such as: detergents, paint, glycerin, fatty acids, varnish, pharmaceuticals or cosmetics, [2]. Raw materials for vegetable oil industry are oilseeds, an important component of modern agriculture. Oilseeds provide easily highly nutritious human food and oil crops and their products represent one of the most important commerce commodity. Vegetable oils are a source of vitamins, calories and essential fatty acids for human diet, at a relatively low cost, [3]. Oil is obtained from oilseed by either solvent extraction or mechanical expression or the combination of the two processes. Mechanical pressing is used for oil recovery up to 90-95%, while solvent extraction is capable of extracting 99%. Mechanical pressing is the most popular method of oil separation from vegetable oilseeds in the world, [4]. For mechanical expression, hydraulic or screw press is employed. Mechanical oil expellers are popular because these equipments have a simple and sturdy construction, can easily be maintained and operated, can be adapted quickly for processing of different kinds of oilseeds, and the oil expulsion process is continuous, the product being obtained within a few minutes from the start of the processing operations. However, the mechanical screw presses are relatively inefficient, leaving about 8-14% of the available oil in the cake, [9]. Thus, in order to reduce the demand and supply gap of vegetable oils in developing countries, it is needed to develop more efficient mechanical screw presses.

Considerable efforts have been made in the past to improve the oil extraction efficiency of screw presses. Most of them have focused on optimization of process variables such as applied pressure, pressing temperature and moisture conditioning of the feed samples [5]. The degree of influence varies with kind of oilseeds and method of oil expression, [1]. Effects of some of these parameters on yield and quality of oil expressed from sunflower using expeller were investigated. A small press of nominal capacity (40 kg/h) was evaluated for cold pressing of undecorticated sunflower seed, [8]. It was observed that narrower choke openings gave lower residual oil in cake, while the press throughput remained virtually unchanged with variation in choke opening. Higher shaft speeds increased the throughput but also increased the residual oil in cake. For a Simon Rosedown Mini-40 screw press was investigated the effects of shaft speed, choke opening and seed pretreatments on pressing performance for canola seed, [10]. The press throughput and oil output both reached a maximum at a seed moisture content of 5% while the residual oil showed a continuous increase with an increases in seed moisture contents. As the choke opening and the shaft speed were lowered, the maximum pressure increased while the press throughput and residual oil both decreased. Some researchers observed that the yield of oil from groundnut increases with a reduction in clearance, [6]. Improvement in the mechanical extraction equipment and techniques through proper conditioning can raise oil recovery from 73% to 80% for rapeseed and groundnut (peanut) and from 60% to 65% for cotton seeds, [7]. Efforts are been made to improve the performance of oil expellers through modifications in press design and by optimization.

This study set out to evaluate the effect of nozzle dimension and the feed rate on oil extraction from rapeseeds using a screw press. Also, in the study it was evaluated the variation of oil yield along the pressing chamber.

METHODS

SK 130/3 oil press used for the experiments from the National Institute of Research - Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest is a screw oil press manufactured by STRÄHLE, Germany, which has the processing capacity of 130 kg/h and the screw speed of 8.9 min^{-1} .

This screw press can be used for pressing various types of oilseeds, such as: rapeseed, sunflower seed, soybean, cameline seed, linseed, castor bean. Depending on the oleaginous material subjected to the pressing, adjustment plates with different thickness are used for varying the oil drainage slots from the pressing chamber. The press is provided with adjustment plates having thickness between 0.1 and 0.8 mm. The pressing chamber is build up from metal bars between which are mounted the adjustment plates to create the strainer for oil discharge. Inside the pressing chamber is the active element of the press which is a variable-pitch screw, composed of six segments, with a constant rotational speed of 8.9 rpm. The cake is discharged through the end of the pressing chamber where six nozzles are provided.



Fig. 1 The compartmented tray for oil collection along the pressing chamber
 1 – compartmented tray; 2 – first compartment of the tray; 3 – the last compartment of the tray; 4 – pressing chamber; 5 – first pressing section (near the feeding section); 6 – the last pressing section (near the cake outlet).

The material subjected to the pressing process was represented by rapeseeds from Triumf variety with a 7.9 % moisture content. The samples of the experiments were made, in all cases, of 12 kg of rapeseeds. One of the variable parameters followed during the experiments was the feed rate of the press with oleaginous material, which was varied by adjusting the position of the flap from the bottom of the feeding hopper: maximum opening,

half opening and fourth opening. Another process variable in the experiments was the diameter of the nozzles for cake evacuation. Therefore, nozzles with diameters of 6.8, 5.8 and 5.2 mm were used. For each of the three types of nozzles, experiments were made for the three position of the adjustable flap from the feeding hopper. During experiments, for oil collection it was used a tray with five compartments, which collect the oil separated from the five segments (sections) of the press (fig.1) in order to determine the oil yield along the pressing chamber. The first pressing section, the next to the feeding section, has 138 mm length, and the following four sections having equals length of 118 mm. After each experiment, the extracted oil was weighed and collected from each pressing section, while the cake was collected and weight from whole the press.

RESULTS AND DISCUSSION

The results obtained at the pressing of 12 kg of rapeseeds, for the three dimensions of the nozzles for cake outlet, as well as for the three opening of the adjustable flap from the feeding hopper are shown in table 1.

Table 1 The results obtained from experiments, for the three nozzles diameter and the three feeding flap opening

Nozzles diameter (mm)	Flap opening	Pressing time (sec)	Recovered oil (g)	Oil yield (%)	Cake obtained (g)	Percent of cake (%)
6,8	maximum	284	3707.4	30.90	8292.6	69.11
	half	305	3844	32.03	8156	67.97
	fourth	316	3927.1	32.73	8072.9	67.27
5,8	maxim	290	4113.3	34.28	7886.7	65.72
	half	311	4299	35.83	7701	64.18
	fourth	327	4354.3	36.29	7645.7	63.71
5,2	maxim	304	4402.1	36.68	7597.9	63.32
	half	331	4528.4	37.74	7471.6	62.26
	fourth	358	4613.3	38.44	7386.7	61.56

The amount of oil obtained in the five sections of the pressing chamber are shown in table 2 and table 3 show the cumulatively percentages of oil recovered along the pressing chamber.

Analyzing the values obtained from experimental research, from table 2, it can be seen that regardless of the type of nozzle used or of the flap opening, on the first section of the pressing chamber (the one next to the feeding section of the press) no amount of oil was recovered. In the second section was obtain the largest amount of oil, after which there was a continuous decrease until the last section, which is placed at the cake outlet from the pressing chamber.

Table 2 Variation of recovered oil along the five pressing sections, for the three nozzles types and for the three flap opening

Nozzles diameter (mm)	Flap opening	Recovered oil by sections (g)				
		I (near feeding)	II	III	IV	V(near cake outlet)
6,8	maximum	0	1878.1	1313.4	356.5	159.4
	half	0	1989.5	1322.2	365.5	166.8
	fourth	0	2006	1375.2	376	169.9
5,8	maximum	0	2078	1436.2	402.3	196.8
	half	0	2101.3	1569.6	424.6	203.5
	fourth	0	2116.6	1593.8	431.6	212.3
5,2	maximum	0	2126.4	1618.7	439.8	217.2
	half	0	2184.5	1660.6	453.4	229.9
	fourth	0	2230.9	1674.4	461.8	246.2

Analyzing the data from table 3, it can be observed that in all experimental situations (different nozzles diameters and different flap opening), the maximum percentage of oil extracted has not exceeded 38.44%. However, the extraction efficiency increases dramatically with decreasing of nozzles diameter, but also with feed rate decreasing.

Table 3 Cumulatively percentage of recovered oil along the five pressing sections, depending on the nozzles types and the feeding flap opening

Lenght of pressing chamber (mm)	Cumulatively percentages of recovered oil (%)								
	Nozzles of 6,8 mm			Nozzles of 5,8 mm			Nozzles of 5,2 mm		
	max. flap opening	half flap opening	fourth flap opening g	max. flap opening g	half flap opening g	fourth flap opening g	max. flap opening g	half flap opening g	fourth flap opening g
138	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
256	15.65	16.58	16.72	17.32	17.51	17.64	17.72	18.20	18.59
374	26.60	27.60	28.18	29.29	30.59	30.92	31.21	32.04	32.54
492	29.57	30.64	31.31	32.64	34.13	34.52	34.87	35.82	36.39
610	30.90	32.03	32.73	34.28	35.83	36.29	36.68	37.74	38.44

Figure 2 shows the influence of the nozzles diameter on the pressing efficiency, for the maximum feeding rate obtained at maximum flap opening. It can be seen that the use of

nozzles with smaller diameter, which involves a higher pressure inside the pressing chamber, leads to better extraction efficiency. Thus, the use of nozzles with 5.2 mm diameter increased the percentage of oil extracted, compared to the cases in which nozzles with diameters of 5.8 and 6.8 mm was used, when the percentage of extracted oil has been smaller.

Also, it can be seen the variation of extracted oil percentage with the length of the pressing sections. On the first pressing section, which has a length of 138 mm, no oil was obtained from the oleaginous material, but, on the second pressing section, with a length of 118 mm (equal to the length of the following three sections) the largest percentage of oil was recovered, while on the last pressing sections oil yield was becoming smaller. Cumulatively, both the amount and percentage of oil expressed increase along the pressing chamber, regardless of the nozzle diameter and the feeding flap opening (fig.2, 3, 4).

Figures 3 and 4 show the influence of nozzles diameter on the pressing efficiency, for half, respectively fourth, flap opening. The same trend as in figure 2 is observed, namely, the use of nozzles with diameters of 5.2 mm increased the percentages of oil obtained, for all three positions of the flap.

In order to analyze the variation of the cumulatively oil percentage expressed along the pressing chamber with the nozzles type at different feeding flap openings, the corresponding graphs were drawn and presented in Figures 5,6 and 7.

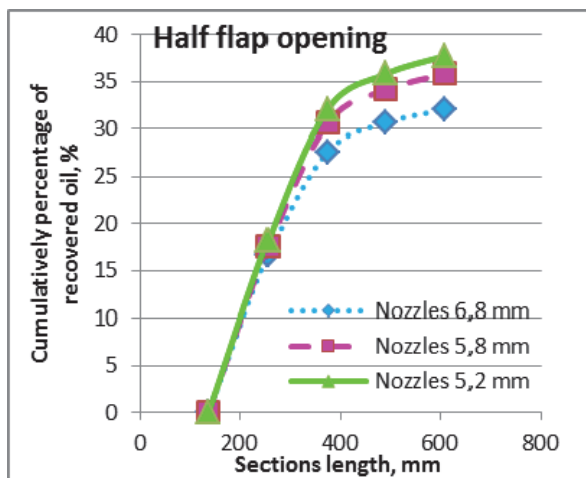


Fig.2 Variation of cumulatively percentage of recovered oil with the length of pressing sections, for the three nozzles types, at maximum feeding flap opening

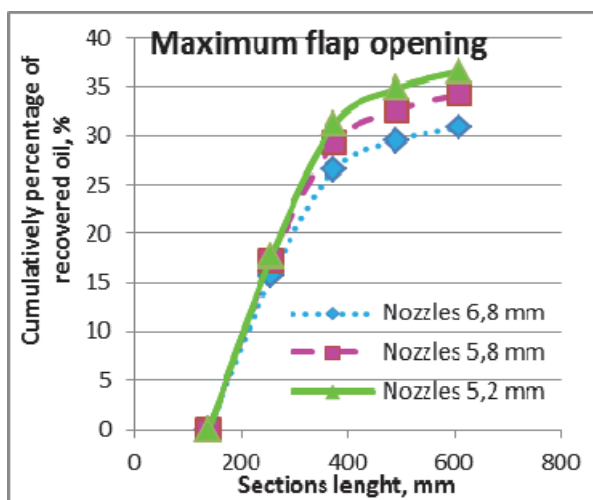


Fig. 3 Variation of cumulatively percentage of recovered oil with the length of pressing sections, for the three nozzles types, at half of feeding flap opening

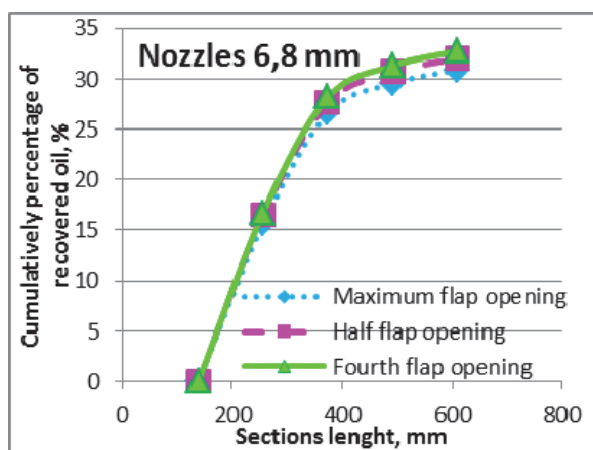


Fig. 4 Variation of cumulatively percentage of recovered oil with the length of pressing sections, for the three nozzles types, at fourth feeding flap opening

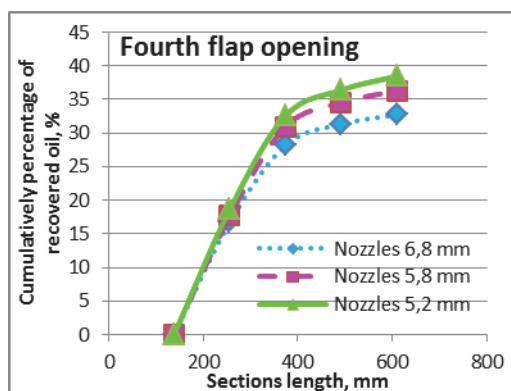


Fig. 5 Variation of cumulatively percentage of recovered oil with the length of pressing sections, for the three flap openings, at 6.8 mm nozzles

Figure 5 shows the variation of feed rate on the cumulatively percentage of recovered oil with the length of pressing sections, in the case of nozzles with diameter of 6.8 mm. The feeding rate was modified by changing the position of the flap from the feeding hopper, during the experiments being taken the maximum, half and fourth opening of the flap. Thus, it can be observed analyzing the figure 2, that the highest cumulatively percentage of obtained oil (32.73%) was recorded for the lowest feed rate, which was obtained at fourth opening of the flap. Instead, for the maximum flap opening, the oil percentage was 30.90% and for half flap opening it was 32.03%.

In figures 6 and 7 it is presented the influence of feed rate on the cumulatively percentage of recovered oil with the length of pressing sections, in the case of nozzles with diameter of 5.8 mm, respectively 5.2 mm. For the 5.8 mm nozzles, the maximum cumulatively percentage of oil was 36.29% in the case of minimum feed rate; and it decreased (at 34.28% for maximum feed rate) by increasing the feed rate.

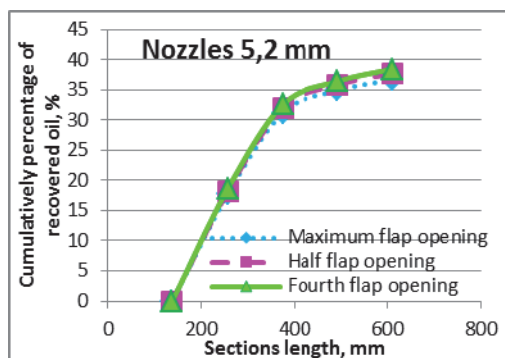


Fig. 6 Variation of cumulatively percentage of recovered oil with the length of pressing sections, for the three flap openings, at 5.8 mm nozzles

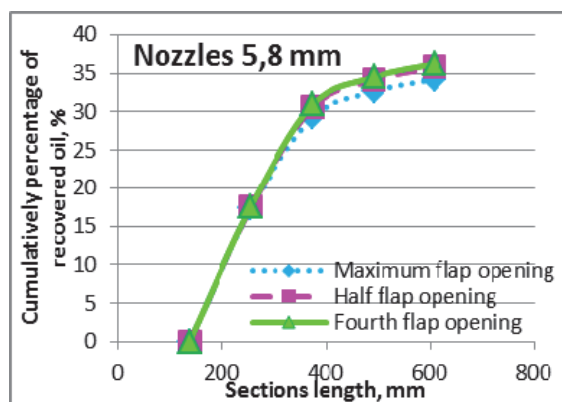


Fig. 7 Variation of cumulatively percentage of recovered oil with the length of pressing sections, for the three flap openings, at 5.2 mm nozzles

Analyzing the figure 7, it is noted the same trend as in figures 5 and 6, the maximum cumulatively percentage of recovered oil (38.44%) is obtained for fourth feeding flap opening, while the minimum percentage (36.68%) is obtained for maximum feeding flap opening. Thus, it can be said that for a maximum efficiency of the pressing process, that meaning in order to obtain the highest percentage of the oil present in the oleaginous material, it is necessary to use for cake outlet nozzles with 5.2 mm diameter and the feeding flap to be as less open.

From the curves analysis from the Figures 2-7 it is observed an increasing tendency of cumulatively oil percentage expressed depending on the pressing chamber length, for different feeding flap openings, as well as for different nozzles diameters for cake outlet. This trend is parabolic, having a little jump to the last section of the pressing chamber, possibly due to the displacement of a small amount of oil together with the pressed material and to its accumulation at the end of the screw, before the cake outlet. Another explanation could be given by the additional pressing of the material (cake) into the nozzles, the oil contained by this being dripped back into the pressing chamber by the exhaust flange walls. We could tell, by observing the distance between the expression curves drawn, that the feeding flap opening, however, has a smaller influence on the oil expression, the distance between curves being smaller compared with the distance between the curves for different nozzles diameter, which is bigger.

On the basis of the cumulatively percentages of expressed oil shown in Table 3, there were graphically represented the data points for the three types of nozzles, but separately for each of the three feeding flap openings, representing the percentage of oil expressed along the pressing chamber (pressing sections). These points, together with the experimental curves are presented graphically in Figures 8, 9 and 10. By computer regression analysis using Microcal Origin vers. 7.0. program, separation curves were plotted using the Rosin-Rammler distribution law, which has the following expression:

$$P_x = 100 \cdot (1 - a \cdot e^{-b \cdot x^c}) \quad (1)$$

where: P_x (%) – represents the cumulatively oil percentage separated along the length x (mm) of the pressing chamber; a , b – constants that depend on the working process parameters of the press and on the physical characteristics of the pressed material.

The coefficients values of the regression equation together with the correlation coefficients values R^2 are shown in Table 4. Studying the graphs from Figures 8, 9 and 10 it is observed that, without considering the first pressing section on which no oil was expressed, along the second pressing section occurs the fastest increasing of the oil yield, while on the next sections the oil yield increases much slower. Maximum percentage of oil obtained was 38.44% and occurred when using 5.2 mm nozzles for cake outlet and a fourth feeding flap opening.

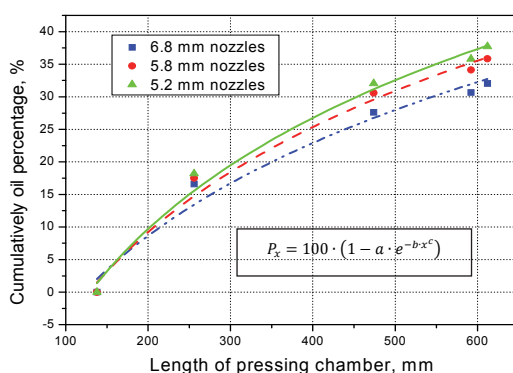


Fig. 8 Variation of the cumulatively oil yield along the pressing chamber, for the three nozzles types, at maximum opening of the feeding flap and the separation curves using the distribution law (1)

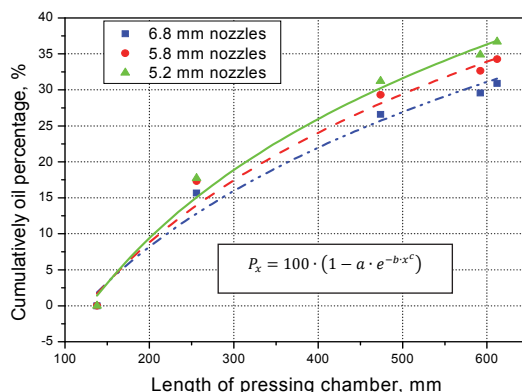


Fig. 9 Variation of the cumulatively oil yield along the pressing chamber, for the three nozzles types, at half opening of the feeding flap and the separation curves using the distribution law (1)

Analyzing the data from Table 4 and the separation curves shown in Figures 8, 9 and 10 it is found that the best correlation of Rosin-Rammler distribution law was obtained when using the nozzles with the smaller diameter (5.2 mm), for the half and fourth feeding flap opening ($R^2 = 0.989$). The poor correlation it is shown by the separation curve for the uses of 6.8 mm nozzle at half opening of the feeding flap.

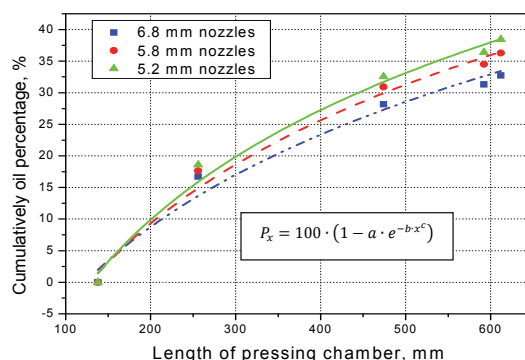


Fig. 10 Variation of the cumulatively oil yield along the pressing chamber, for the three nozzles types, at fourth opening of the feeding flap and the separation curves using the distribution law (1)

Table 4 Coefficients values of the Rosin-Rammler regression equation and of the R^2 correlation coefficient, for the three nozzles types and the three feeding flap openings

Flap opening	Nozzles diameter (mm)	Regression equation coefficients and the correlation coefficient			
		a	b	c	R^2
at maximum	6.8	1.366	0.029	0.495	0.979
	5.8	1.442	0.035	0.484	0.98
	5.2	1.566	0.05	0.452	0.988
at half	6.8	1.398	0.032	0.485	0.977
	5.8	1.54	0.048	0.454	0.987
	5.2	1.61	0.055	0.446	0.989
at fourth	6.8	1.402	0.032	0.492	0.979
	5.8	1.543	0.047	0.458	0.987
	5.2	1.628	0.056	0.445	0.989

CONCLUSIONS

The oil expression process from oilseeds using screw presses is influenced by a number of parameters, of which the most important are the physicochemical properties of the seeds and constructive-functional characteristics of the presses. For the SK 130/3 oil press, in all the experimental cases tested, on the first section of the pressing chamber, which is near the feeding section with material, no oil was obtained, while in the second section the highest

oil amount was expressed. From here to the last section of the press the oil expressed has a continuous decrease. The maximum cumulatively percentage of recovered oil was 38.44% and it was obtained when using the nozzles for cake outlet with 5.2 mm diameter, for fourth feeding flap opening. Instead, the minimum percentage of recovered oil was 36.68% and was obtained for 6.8 mm nozzles diameter, for a maximum feeding flap opening. Thus, it can be said that the process efficiency substantially increases with the decreasing of the nozzles diameters, but also with the decreasing of the feed rate. From the curves analysis from the Figures 1-6 it is observed an increasing tendency of cumulatively oil percentage expressed depending on the pressing chamber length, for different feeding flap openings, as well as for different nozzles diameters for cake outlet; this trend is parabolic. However, the feeding flap opening has a smaller influence on the oil expression compared with the influence of the nozzles diameter. By regression analysis using Microcal Origin vers. 7.0. program, using the Rosin-Rammler distribution law, it was found that the best correlation of the cumulatively oil percentage curve was obtained when using the nozzles with the smaller diameter (5.2 mm), for the half and fourth feeding flap opening ($R^2 = 0.989$). The poor correlation it is shown by the separation curve for the uses of 6.8 mm nozzle at half opening of the feeding flap.

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KINEMATIC-STRUCTURAL ANALYSIS OF ACTUATING MECHANISM OF A CONICAL SIEVE WITH OSCILLATING MOVEMENT

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ABSTRACT

In the paper is analyzed the actuating mechanism of a vertical conical sieve, with oscillatory motion, used both to first cleaning of seeds from impurities, as well as for calibration (grading) by size of seeds.

The mechanism is on the type with oscillating slide and balancer, composed of a worm-worm wheel mechanism with eccentric, complemented by two dyads one RTT and one RRT.

It shows the kinematic scheme of the mechanism and its equivalent scheme and is made the kinematic analysis leading to oscillatory motion of conical sieve. Were calculated on the equivalent mechanism displacements, velocities of these points and there were graphically presented their variations for more oscillation frequencies and several lengths of the connecting arm with sieve.

On the simplified model of the mechanism were calculated marginal amplitudes of the conical sieve for the lengths of the connecting arm with sieve, used in kinematic analysis performed.

Key words: conical sieve, oscillating movement, dyad RTT, dyad RRT,

INTRODUCTION

Actuating of sieve and of sieve blocks for grain cleaning impurities is done, usually, with actuating mechanisms with eccentric or crank gear type, [1,4].

These mechanisms achieves an amplitude relatively large of oscillations and a low frequency of oscillation.

Lately are used more and more vibrating motors with counterweights for actuating of oscillating separator and of sieve blocks, having a high frequency oscillation and small amplitude of oscillations.

Motion of actuating mechanisms of separators and sieve blocks is conditioning the separation surface movement, respectively the material particles motion from this. Therefore, through kinematic analysis of actuating mechanisms can determine the kinematic characteristics of the sieves, respective of separation surfaces, allowing the estimation of the movement of material particles.

Thus, in paper [3] is analyzed an actuating mechanism, parallel type, for actuating of vibrating sieves and presents a mathematical model for kinematic analysis of the mechanism. Based on the results were plotted track curves of sieves. Mathematical model equations were the basis of a simulation in 3D of sifted material trajectory.

Furthermore, Lizhe in paper [2] shows the dynamic and numerical analysis of a actuating mechanism of sifting sieves and mathematical model for determining of equations of motion. It shows that for non-periodic dynamic responses of sieve mechanism movement induced to separation surface, respective particles of material, is chaotic.

In this paper is analyzed structural and kinematic an actuating mechanism with oscillating slide and balancer for actuating of a suspended conical sieve with movement considered oscillatory harmonic.

MATERIALS, METHODS AND PROCEDURES

For cleaning of impurities of cereals and seeds of other crops can use various types of equipments, of which the most important are the sieve blocks. In order to carry out sifting, they must realize an oscillatory motion to create a relative motion of material on the separation surface.

For the study of vibrational phenomena at equipments from processing field of agricultural products, within paper [5] were conceived, designed and made an experimental stand which comprises a conical outer separation surface with vertical spindle, suspended in three equidistant points, at an equal distance from the vertical axis of the cone, with three metal wires, both at the top and at the bottom.

Experimental installation scheme is shown in fig. 1, [5].

Sieve movement can be considered an alternative circular motion with very small displacements on the arm direction if not take into account the vertical movement of sieve (displacement which can be neglected due to its extremely low values).

Since the movement of the sieve 1 (fig.1) along of link arm (7) with actuating mechanism (3) is very small (the order of hundredths of a millimeter), this movement restriction can be inserted at a purely circular oscillating movement by a central vertical axis around which oscillation is carried out.

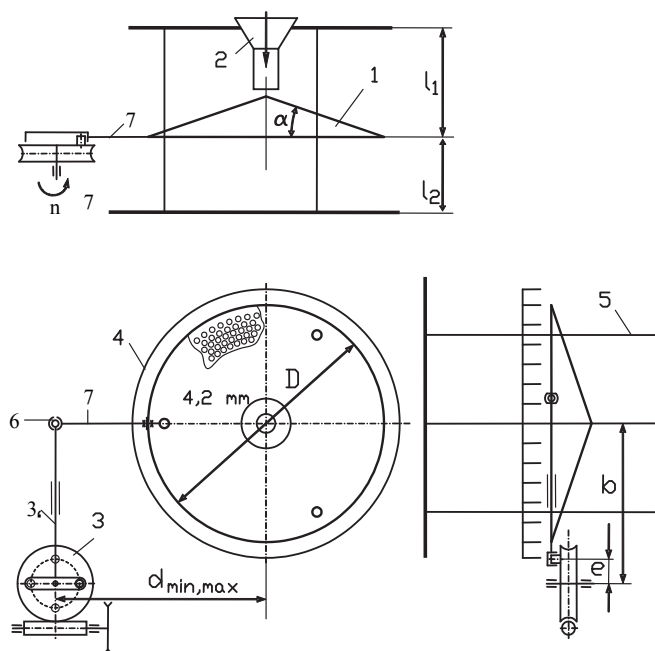


Fig. 1 Scheme of the experimental stand with suspended conical sieve, [5]; 1.conical sieve with circular apertures; 2.feed hopper; 3.actuating mechanism with worm gear and slide swing; 3'.slide swing arm; 4.separated material collecting box;5.metal wires for suspending; 6.spherical joint; 7.radial arm for linking the actuating mechanism with sieve

Theoretical considerations

Due to the fact that the conical sieve is suspended in three equidistant points circumferentially, both the top, and at bottom, assuming a certain elasticity of the suspension metal wires, displacement of sieve during the oscillation movement is a complex movement, uncontrolled.

It can be, however, considered, a circular alternative motion, due to its tangential actuation at distance d from the center C (from fig.2).

a) Simplifying assumption for analysis

For dynamic study of vibrating machine with conical surface separation was conceived a schematic representation (fig.2) of it and have been used a few assumptions as:

- center of mass of the assembly conical sieve – linking arm with actuating mechanism is always horizontal and in the radial direction of the linking arm (neglecting the vertical movement of the sieve);
- movement of actuating system button was considered a harmonic oscillatory linear motion leading to displacement in two directions (in a horizontal plane) of conical sieve center and the whole separation assembly;

- in these conditions sieve movement becomes a plane parallel motion defined by two parameters (in the polar coordinate system);
- separation surface of the conical sieve is considered a plane surface, without taking into account the influence of apertures on the general movement of sieve;
- was neglected the influence of air flow on separation equipment;
- Was considered a uniform elasticity of suspension wires, through different elastic constants of the wires at the top and bottom, (was take into account of their elongation at its horizontal displacement).

b) Determination of movement amplitude

By assuming that the center of the sieve is moving only on axis Ox (fig.2), it is possible to calculate the displacement on axis Oy of sieve points. It is assumed that the amplitude of the sieve is the maximum displacement on the axis Oy of point N from the circumference of it to the (N_1, N_2) , corresponding to angle φ , on both sides of the axis Ox, that is made by the linking arm with actuating mechanism during oscillation of the sieve. Sieve course is noted with S, and amplitude of oscillation with A_i (circumferentially). At the extreme end of the linking arm O_oM_o , displacement of the sieve was noted with A_e , being, obvious, greater than the inner displacement A_i (see fig.2). Considering the geometric characteristics of the suspended conical sieve and those of the actuating mechanism, for a distance d (of actuating) known (fixed, but adjustable), can calculate displacement A_i (in the assumption considered).

Are known:

$D_s = 2 \cdot r = 430 \text{ mm}$ – sieve diameter at its edge;

$S = 2A_e = 16 \text{ mm}$ – course of actuating mechanism button;

$A_e = 8 \text{ mm}$ – amplitude (displacement) of arm movement.

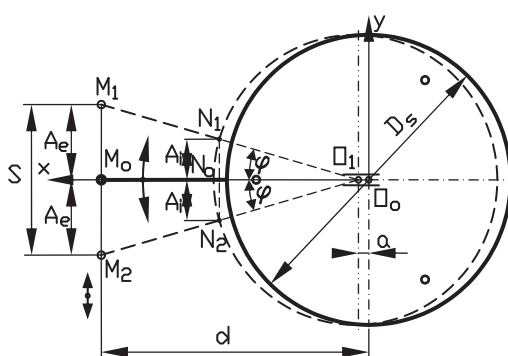


Fig. 2 Scheme for calculation of sieve oscillation amplitude

Within experimental determination, distance d (length of linking arm with actuation mechanism) was set successive at four values, by moving on the proper framework of the mechanism, so by changing on direction Ox of point M_o position.

Thus, values of this range was: $d_1 = 480$ mm; $d_2 = 460$ mm; $d_3 = 440$ mm; $d_4 = 420$ mm, which lead, evident, at four different values of the oscillation amplitude (calculated geometrically). For known values of sieve linking arm length d and a course $S=16$ mm of actuating mechanism eccentric, results displacements of sieve characteristic position O and N_1 (N_0N_1 and N_0N_2) from table 1.

Table 1. Amplitude A_i values for known lengths of sieve arm

d (mm)	φ (°)	a (mm)	A_i (mm)
480	0.955	0.067	3.58
460	0.966	0.070	3.74
440	1.042	0.073	3.91
420	1.091	0.076	4.10

c) Kinematic analysis of the sieve actuating mechanism

Mechanism from fig. 1 was equated with the mechanism from fig. 3, on the assumption that center of conical sieve has only translational movement in the direction Ox , using elements of mechanisms theory.

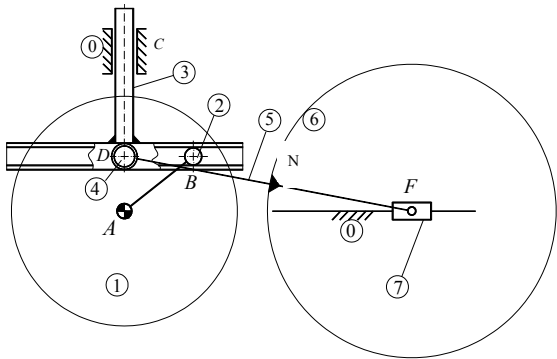
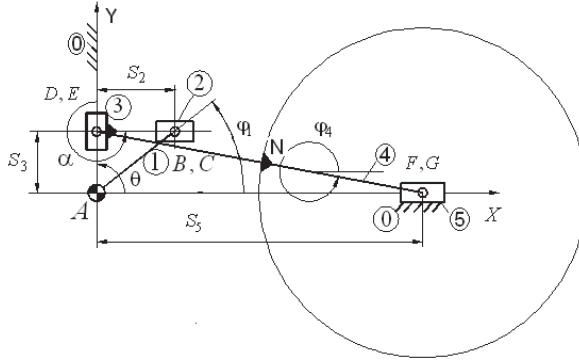


Fig. 3 Constructive-kinematic scheme of the conical sieve actuating mechanism; 1.worm wheel; 2.crank button; 3.guide rod; 4.bolt; 5.linking arm; 6.suspended conical sieve; 7. guidance

In this situation mechanism from fig.4, gas an element for rotation drive AB , which is represented in real mechanism of worm wheel and its eccentric button and two, one RTT , represented by the points BCD in equivalent mechanism and a dyad RRT, represented by the points EFG , in which point G represents the center of sieve, (with translational movement).

CD element, represents rod of actuating mechanism, while the element EF represents linking arm of sieve with its center. For achieving kinematic scheme from fig.3, was subjected, first at equivalence of upper hitch from point B , hitch which was converted to an

element and two inferior hitches. Doing synthesis of mechanism and writing characteristic equations in calculation program Turbo Pascal were determined displacements of points E, in the direction of the actuation rod, identical to point M (M_0, M_1, M_2 from fig.4), as well as displacement of point N (N_0, N_1, N_2 from the same figure) on Oy axis, considered in the paper as the sieve oscillation amplitude.



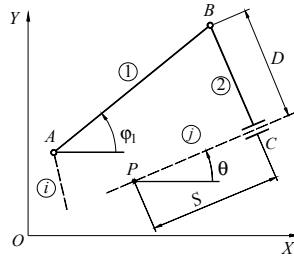


Fig. 5 Kinematic scheme of dyad *RRT*

The iterative calculation process stops when difference of two solutions calculated consecutively is less than one ε imposed, i.e.:

$$|\varphi_1^{(i+1)} - \varphi_1^{(i)}| < \varepsilon, \quad |S^{(i+1)} - S^{(i)}| < \varepsilon.$$

The initial solution is:

$$\begin{aligned} \varphi_1^{(0)} &= \text{ATAN2}(YB - YA, XB - XA); \\ S^{(0)} &= \sqrt{(XP - XC)^2 + (YP - YC)^2}, \end{aligned}$$

where: XB, YB , represents approximate coordinates of the point B , and XC, YC coordinates of perpendicular leg taken from the point B on the translation right.

Kinematic analysis of dyad *RTT*

In fig 6.a is presented kinematic scheme of dyad *RTT*. From the point of view of the positions, this structural group has two solutions, as seen in fig 6.b.

- For the determination of kinematic parameters of the dyad *RTT*, are known:
- $AB = D$ - distance from the hitch center A to the right BC ;
- XA, YA - coordinates of external hitch A ;
- XP, YP, θ - the translational right from hitch C ;
- - angle between vectors $\overline{PC}$ and $\overline{CB}$, attached to translation rights from hitches C and B ($\alpha \neq k\pi$);
- - $\dot{X}A, \dot{Y}A, \dot{X}P, \dot{Y}P$ - projections of linear velocities of points A and P ;
- - $\dot{\theta}$ - angular velocity of the element j ;
- - $\ddot{X}A, \ddot{Y}A, \ddot{X}P, \ddot{Y}P$ - linear acceleration projections of points A and P ;

- $\ddot{\theta}$ - angular acceleration of the element j .

Is determined:

- S_1, S_2 - variable parameters of translational hitches B and C ;
- $\dot{S}_1, \dot{S}_2$ - relative velocities of translational hitches B and C ;
- $\ddot{S}_1, \ddot{S}_2$ - relative acceleration of translational hitches B and C .

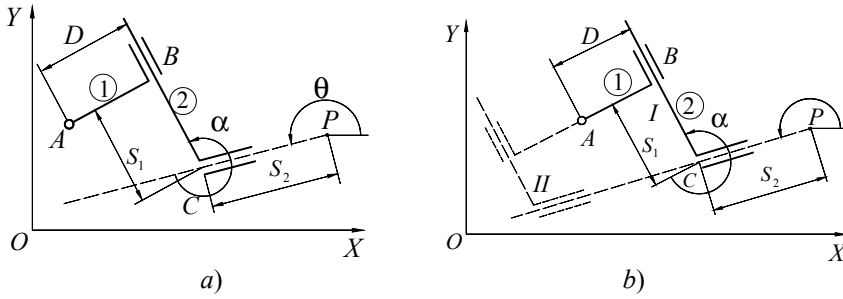


Fig. 6 Kinematic scheme of dyad *RTT*

Analysis of the RTT dyad positions

The positions equation system is obtained by projecting vectorial equation $\overline{OA} + \overline{AB} = \overline{OP} + \overline{PC} + \overline{CB}$ on the axes of coordinate system, namely:

$$\begin{cases} S_1 \cos(\theta + \alpha) + S_2 \cdot \cos \theta = XA - XP + AB \sin(\theta + \alpha) \\ S_1 \sin(\theta + \alpha) - S_2 \cdot \sin \theta = YA - YP - AB \cos(\theta + \alpha) \end{cases}$$

The positions equation system is linear in the unknowns S_1 and S_2 . The system solution is:

$$\begin{bmatrix} S_1 \\ S_2 \end{bmatrix} = A^{-1} \begin{bmatrix} A1 \\ A2 \end{bmatrix},$$

where:

$$A = \begin{bmatrix} \cos(\theta + \alpha) & \cos \theta \\ \sin(\theta + \alpha) & \sin \theta \end{bmatrix}, \text{ is the matrix of unknown coefficients } S_1, S_2;$$

$$A1 = XA - XP + AB \sin(\theta + \alpha);$$

$$A2 = YA - YP - AB \cos(\theta + \alpha).$$

System determinant being: $\det(A) = -\sin \alpha$, should be $\alpha \neq k\pi$.

As shown in fig 6, dyad *RTT* has two solutions, iand to determine each of them have adopted two methods.

Analysis of the RTT dyad velocities

By derivation of position equation system relative to time, is obtained a system of two linear equations in unknown $\dot{S}_1$ and $\dot{S}_2$:

$$\begin{cases} \dot{S}_1 \cos(\theta + \alpha) + \dot{S}_2 \cos \theta = B1 \\ \dot{S}_1 \sin(\theta + \alpha) + \dot{S}_2 \sin \theta = B2 \end{cases}$$

where:

$$\begin{aligned} B1 &= \dot{X}A - \dot{X}P + D11\dot{\theta}, & D11 &= AB \cos(\theta + \alpha) + S_1 \sin(\theta + \alpha) + S_2 \sin \theta; \\ B2 &= \dot{Y}A - \dot{Y}P + D12\dot{\theta}, & D12 &= AB \sin(\theta + \alpha) - S_1 \cos(\theta + \alpha) - S_2 \cos \theta. \end{aligned}$$

Using the inverse matrix method, results:

$$\begin{Bmatrix} \dot{S}_1 \\ \dot{S}_2 \end{Bmatrix} = A^{-1} \begin{Bmatrix} B1 \\ B2 \end{Bmatrix}.$$

Analysis of accelerations in dyad RTT

By derivation of velocity equations sytem relative to time, is obtained a system of two linear equations in unknown $\ddot{S}_1$ and $\ddot{S}_2$:

$$\begin{cases} \ddot{S}_1 \cos(\theta + \alpha) + \ddot{S}_2 \cos \theta = C1; \\ \ddot{S}_1 \sin(\theta + \alpha) + \ddot{S}_2 \sin \theta = C2, \end{cases}$$

where:

$$\begin{aligned} C1 &= \ddot{X}A - \ddot{X}P - D12\dot{\theta}^2 + (\dot{S}_1 \sin(\theta + \alpha) + \dot{S}_2 \sin \theta)\dot{\theta}; \\ C2 &= \ddot{Y}A - \ddot{Y}P + D11\dot{\theta}^2 - (\dot{S}_1 \cos(\theta + \alpha) + \dot{S}_2 \cos \theta)\dot{\theta}. \end{aligned}$$

Using the inverse matrix method, results:

$$\begin{Bmatrix} \ddot{S}_1 \\ \ddot{S}_2 \end{Bmatrix} = A^{-1} \begin{Bmatrix} C1 \\ C2 \end{Bmatrix}.$$

Based on the presented mathematical model relationship, were prepared procedures and calculation programs which were the basis for determining variation charts of the positions and velocities of mechanism characteristically points. For the determination of kinematic parameters of mechanism elements, were considered 360 equidistant positions of the element 1 (fig.3) with step of 1° . Results obtained from calculation program developed in

the language Turbo Pascal were processed in MS. Excel v.12, and were plotted variation charts of points E displacements and velocities, respective N represented in fig.7 – fig 9 , for the four OM arm lengths.

Were considered three values of the oscillation frequency of the sieve (used in experimental determinations): 250, 520 and 790 osc./min.

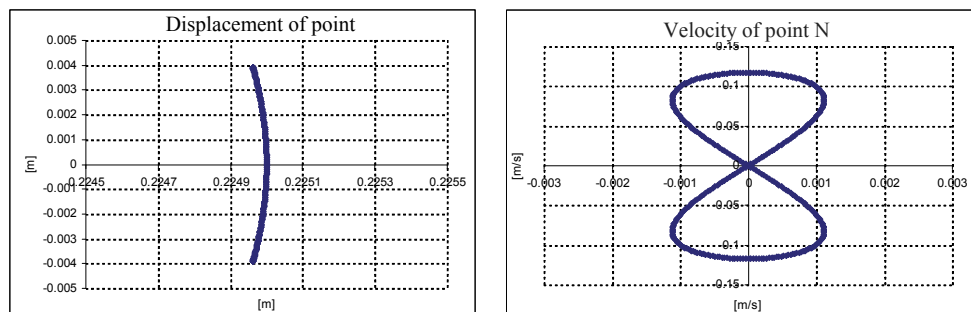


Fig. 7 Displacement, respective hodograph of point N velocity for $d=440$ mm and sieve oscillation frequency of 250 osc./min.

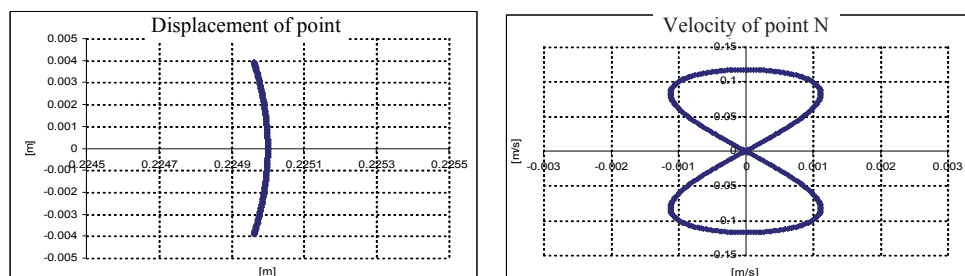


Fig. 8 Displacement, respective hodograph of point N velocity for $d=460$ mm and sieve oscillation frequency of 520 osc./min

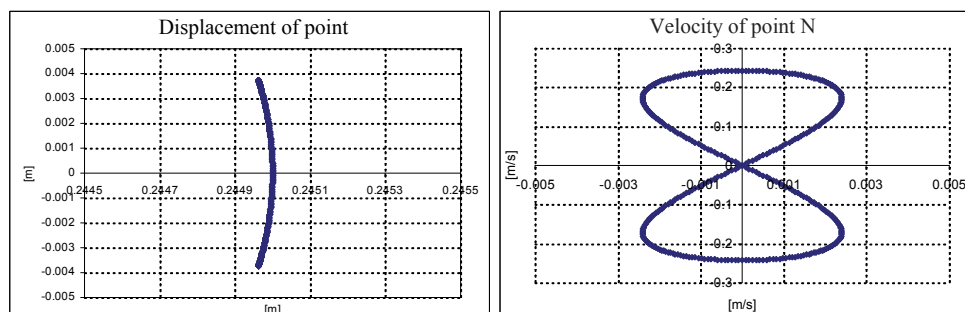


Fig. 9 Displacement, respective hodograph of point N velocity for $N d=480$ mm and sieve oscillation frequency of 590 osc./min

CONCLUSIONS

By structural and kinematic analysis of grain cleaning sieves actuating mechanism, can be estimated the material particles motion on the separation surface, considering that its action shall be sent to the particles.

In the paper is presented a mathematical model of analyzing for a mechanism with oscillating slide and balancer for actuating of a conical sieve with vertical shaft.

Based on a simplified model of actuating mechanism were determined the positions and velocities of characteristic points of sieve for three oscillation frequencies and four lengths of linking arm. Were determinate, as well, sieve amplitude values for the four lengths of the linking arm of mechanism with sieve.

Analysis of the results obtained and of plotted charts, both for positions and velocities of linking point with sieve of actuating mechanism, it shows a harmonic oscillation of its, considering the simplifying assumptions from the paper.

These results can be used by specialists both for the design of similar mechanisms, and for choosing the appropriate parameters of sieving working regime.

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MONITORING THE DRYING PROCESS OF VEGETAL PRODUCTS BY USING INFRARED IMAGES

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ABSTRACT

The paper presents a theoretical and experimental approach regarding the influence of temperature on the quality of food products. Researches are focused on measuring of the vegetables slices temperature as a key parameter in the drying process control. Taking in consideration a study about the possibility of temperature measurement, including non-contact techniques, the infrared measurement technology provide the best solution. Infrared imaging has already been done for monitoring the drying process for paper, rough surfaces), wood industry, protein-sugar mixtures and citrus surface. However, infrared imaging has not yet been used for agricultural products, such as sliced vegetables and fruits. Further, there are presented experimental results at the apple slice drying, emphasizing the advantages of infrared images uses: monitoring of the whole product's temperatures is easy and informative; a critical temperature can be assessed, it can be demonstrated when the product is overheated; direct observation allows to see defects of the drying process immediately; automatic control of the drying process by measuring product temperature is possible and provide the best solution, preserving the quality and reducing the drying energy consumption.

Key words: vegetal products drying, infrared images, monitoring temperature

INTRODUCTION

Infrared cameras convert infrared radiation into colors of the visible spectrum. They are used in many fields where temperatures are observed and knowledge about temperatures of an area is more significant than of only one spot. Their advantage to common temperature sensors is that no contact between object and sensor is needed and interruption of drying process can be prevented. Temperature plays the most crucial role in a drying process and influences the quality of the product. Vegetables and fruits consist of numerous nutrients and the objective of drying is to preserve foods without big loss of nutrients. (Mnerie G.V., at all, 2012) But not only nutrients, also color, texture and flavor change when the temperature is too high. Only very few temperature changes cause a much greater loss of food quality and product temperature is a relevant parameter which should be considered during drying. Empirically adjusted drying air temperature of 50°C is known to prevent great loss of nutrients, but it does not prevent the product from overheating at the end of the drying process. Investigating the product temperature by infrared cameras helps to stop the deteriorative impact of heat, which happens in the end of the drying process when the product heats up. (Liviu Gaceu, Badea Lepadatescu, 2009).

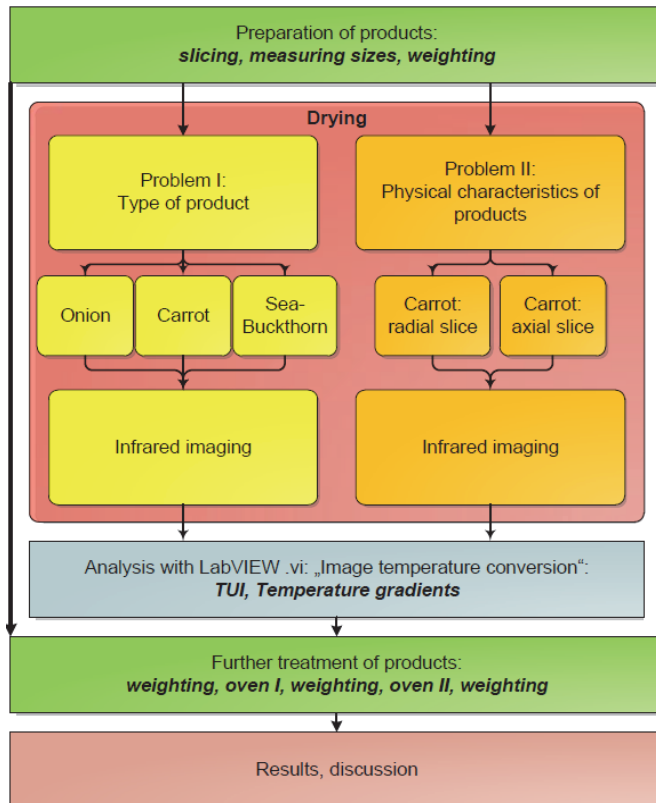


Figure 1 The variation of the parameters of the grain drying process

METHOD

Infrared imaging has already been done for monitoring the drying process for paper industry rough surfaces, wood industry, protein-sugar mixtures and citrus surface. However, infrared imaging has not yet been done for agricultural products, such as sliced vegetables and fruits. (Gaceu, L. 2009)

Through a successful research the following objectives should be achieved:

- visualizing of the temperature distribution during drying by obtaining infra-red images.
- development of a tool to evaluate the acquired infrared images. Therefore, a .vi written in LabVIEW is supposed to convert pixel values of colors into temperature values, and maximum, minimum and average temperature of each image is imported into Microsoft Excel®.
- identification of advantages and limitations for thermography measurements in industrial drying processes.
- preparation of an automatic control with product temperature as command variable by using a LabVIEW .vi.

For achieving these objectives, the methodology shown in 1 was used.

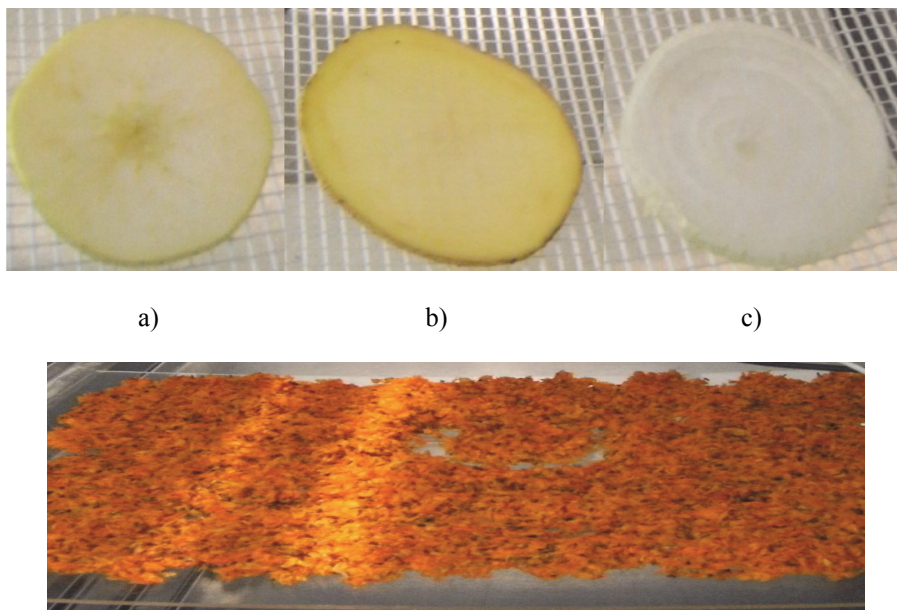


Figure 2 Apple slice (a), potato slice (b) and onion slice (c) prepared for drying

For the experiment apples, onions, potatoes, carrots and the remnants of pressed seabuckthorn were dried. Prior to the experiment, they were bought at a local merchant and the

sea-buckthorn remnants were prepared by the laboratory staff. When apple, onion and potato temperature reached room temperature, the products were cut into slices and in the case of carrot, sliced and cut into adequate size for the project. Important for the success of the experiment were similar thicknesses for comparative studies. The products are presented in fig. 2 and had thicknesses from Table 1.

Table 1 Thickness and weight of product slices

Product	Thickness in mm
Apple	$2,35 \pm 0,05$
Potato	$2,45 \pm 0,15$
Onion	$2,4 \pm 0,1$
Carrot	$2,4 \pm 0,1$
Sea-Buckthorn	10

For the experiment a cabinet dryer of the size 2.20m x 1.12m x 2.30m [l x b x h] was used. The dryer consists of the parts shown as schematic chart in Figure 3. The drying oven allows the control of temperature in the range of 30...60 degrees. The drying process was focused for obtaining o high quality products, so the drying temperature was fixed to the 55 C value.

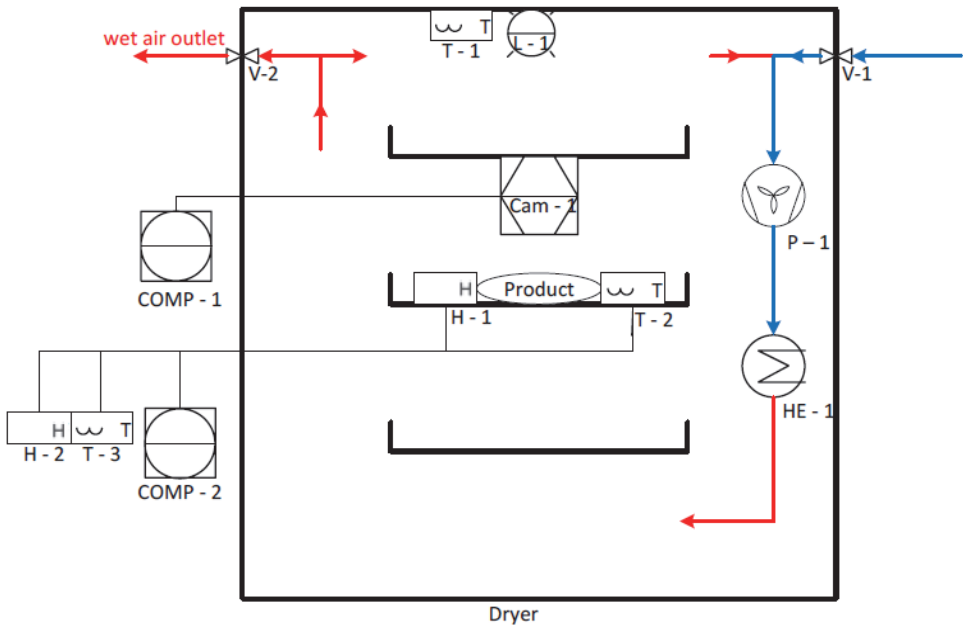


Figure 3 Schematic chart of the dryer

The process takes 350 minutes in order to decrease the material humidity for long term storage. The weight of the onion slice varies between: 46.7 g at the beginning process to 5,7 g at the end of the drying process.

For the experiment a special tray was made of mesh fibers to provide good heat transfer. The dryer has an air inlet (V – 1) and outlet (V – 2). Fresh, cold, dry air from the outside is mixed with hot drying air inside the dryer. P – 1 is a ventilator and sucks the air into the heat exchanger (HE – 1), where the air is heated up. After that, the hot, dry air is dispersed in the whole dryer. The pre-set drying temperature of 50°C was regulated with a PID regulation by comparing temperature T-1 with the reference temperature. Next to T – 1 is a light arranged (L – 1) that can be turned on upon need. There are 2 additional temperature and humidity sensors used for the experiment. The temperature sensor T – 2 and humidity sensor H – 1 are placed next to the product inside the dryer. The humidity sensor H – 2 and temperature sensor T – 3 are placed outside for measuring the room temperature and humidity. These four sensors are linked to a computer (COMP – 2). The infrared camera (Cam – 1) is arranged on the upper tray of the wagon and focused towards the product. The infrared camera is linked to a computer placed outside (COMP – 1). On this computer the infrared images are processed.

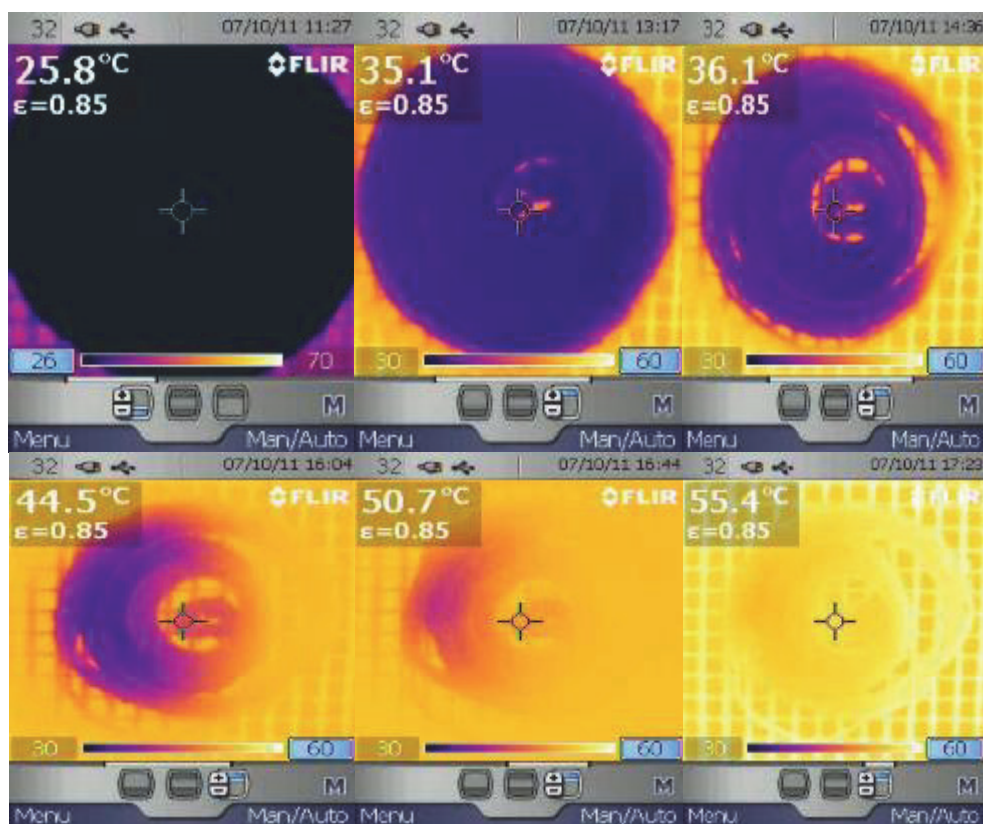


Figure 4 Different thermal images from different stages of drying process of onion

The acquisition of the surface products temperature (figure 4) was done using an infrared thermal scan camera type FLIR i50. with the following technical characteristics:

- Thermal sensitivity/NETD $<0.10\text{ }^{\circ}\text{C}$ ($<0.18\text{ }^{\circ}\text{F}$) @ $+25\text{ }^{\circ}\text{C}$ ($+77\text{ }^{\circ}\text{F}$) / 100 mK ;
- Image frequency 9 Hz;
- Focus Manual;
- IR resolution 240×240 pixels;
- Display Built-in 3.5 in. LCD, 256k colors, 240×320 pixels;
- Object temperature range -20 to $+120\text{ }^{\circ}\text{C}$ (-4 to $+248\text{ }^{\circ}\text{F}$);
- 0 to $+350\text{ }^{\circ}\text{C}$ ($+32$ to $+662\text{ }^{\circ}\text{F}$);
- Accuracy $\pm 2\text{ }^{\circ}\text{C}$ ($\pm 3.6\text{ }^{\circ}\text{F}$) or $\pm 2\%$ of reading.

Infrared camera was connected with a laptop and the images were converted into numerical matrix using LabVIEW software (fig. 5). The images have 240×240 pixels, each of them showing the temperature of one point of the surface o material. In table 2, a list with all front panel elements is presented. (Gaceu, L., 2008)

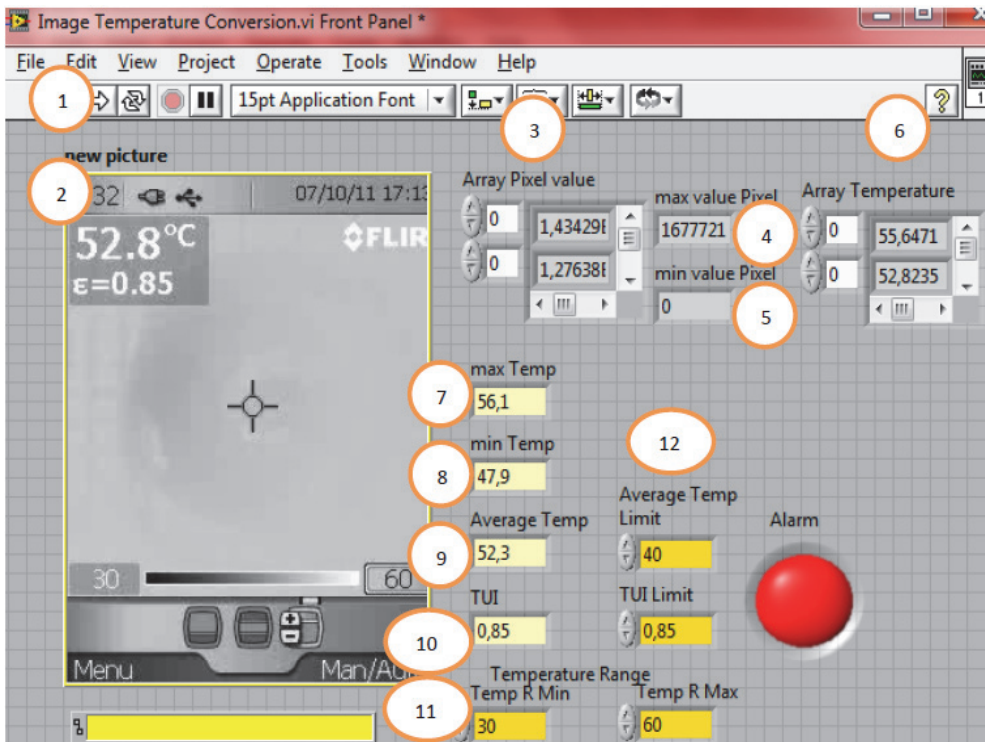


Figure 5 Front Panel of LabVIEW VI “Image Temperature conversion”

Table 2 List of elements of the front panel

No.	Name	Description
1	Run program	When clicking this button the program starts and asks for the .jpg image to load.
2	new picture	Display of the actual, loaded .jpg image with the compatible path to file.
3	Array Pixel value	The values of each pixel for the whole image shown in a 2D-array.
4	max value Pixel	The maximum value from the 2D-array "Array Pixel value".
5	min value Pixel	The minimum value from the 2D-array "Array Pixel value".
6	Array Temperature	A 2D-array with temperature values.
7	max Temp	The maximum temperature from the 2D-array "Array Temperature".
8	min Temp	The minimum temperature from the 2D-array "Array Temperature".
9	Average Temp	The average of all temperatures from the 2D-array "Array temperature".
10	TUI	The temperature uniformity index is $\text{min Temp} / \text{max Temp}$
11	Temperature Range	At the start of the drying process, the temperature range is manually adjusted at the camera settings. These settings need to be transferred to the front panel. The temperature range indicates the minimum and maximum temperatures from the measurement during drying.
12	Average Temp Limit; TUI Limit	Two controls that indicate the drying characteristics. The input defines when an alarm is triggered.

RESULTS AND DISCUSSION

The infrared pictures were converted into a matrix of values by applying different tools available in LabView (Ellen Schur, Gaceu Liviu, 2012). The component values are stored as integer numbers in the range 0 to 255, the range that a single 8-bit byte can offer (by encoding 256 distinct values). These may be represented as either decimal or hexadecimal numbers. Furthermore, the numerical matrix can be analysed and it is possible to show in real time some important values, like:

- the mean temperature of the product surface;
- the coefficient of non uniformity temperature;
- the minimum/maximum temperature value on the surface of material;
- an overheating blinker that will be used for controlling of the dryer heater.

It can be observed that the onion slice suffers a phenomenon of splitting in circular layers (figure 6). This makes difficult the measuring of the product temperature, especially if it can use an infrared pyrometer. Since this device measures the temperature just in one point, and sometimes this point can become out of the product surface, the temperature informati-

on is useless. This emphasized an advantage of infra-images which measure temperature in $240 \times 240 = 57600$ points.

For monitoring the drying process and visualizing in real time the temperature pattern, it was used the VLC player. This allows the viewing of the current infrared images, and captured automatically one picture/10 min. The pictures were saved into a dedicated local folder. In this way, VLC player consists also into an interface between FLIR camera and LabView software, used as the following. For having an overview of the entire drying process and for making some correlations regarding the drying process were measured 4 other thermal parameters such: the air temperature inside and outside of the drying oven; the air humidity inside and outside of the drying oven.

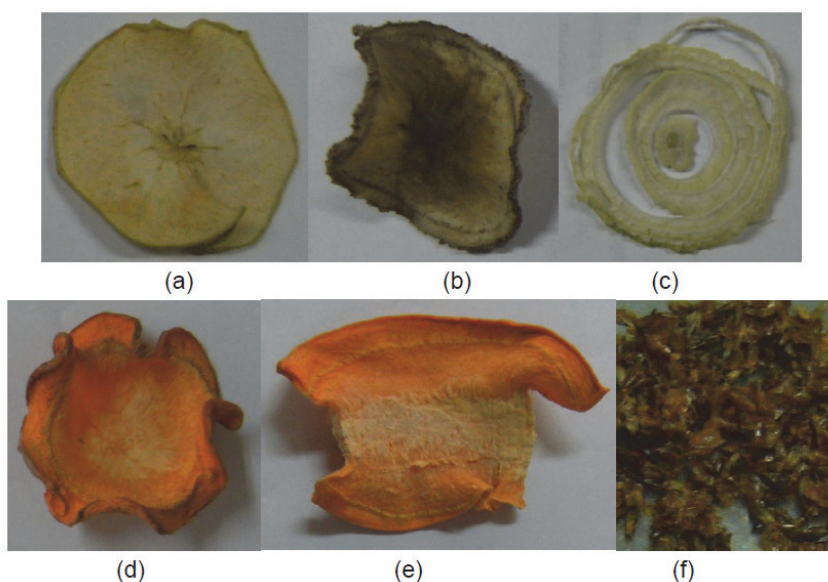


Figure 6 Products after drying: (a) apple, (b) potato, (c) onion, (d) radial carrot, (e) axial carrot, (f) sea-buckthorn

This was done by using a Nova Fourier system, which allows connecting a series of dedicated sensors. After the experiment, the products were weighted again. The removal of the remaining moisture in the dried products was done following these steps:

- 105 °C for 3 hours in the first oven. Remaining material was substances without water, dry matter.
- 600 °C for 8 hours in the second oven. Remaining material were mineral substances, calcinized matter.

After the first and second ovens the materials were weighted again for water subtraction. The results are shown in Table 3.

Table 3 Product weights

Product	Before drying [g]	After drying [g]	After 1st oven [g]	After 2nd oven [g]
Apple	7,71	1,21	1,09	0,1
Potato	13,22	3,05	2,79	0,12
Onion	10,68	1,47	1,26	0,04
Carrot – radial	11,45	1,75	1,53	0,44
Carrot - axial	14,06	2,75	1,71	1,03

CONCLUSIONS

The experimental researches showed the following conclusions:

Temperature is the most important criteria for controlling the drying process. Temperature influences drying rate, drying efficiency, process costs and product quality. However during conventional drying processes drying air temperature is the only controlled parameter, whereas product temperature is the intrinsic parameter influencing product quality. A possibility to control the drying process by product temperature is infrared thermography. *Advantages and limitations* of using infrared cameras for drying processes are:

- the using of infrared capture images consist a proper noninvasive technique for monitoring the surface temperature of the dried agricultural products;
- a critical temperature can be assessed, it can be demonstrated when the product is overheated
- the infrared measuring technique shows the non-uniformity of the surface temperature, an important parameter for avoiding supplemental thermal stress of the products slices; gradients following the TUI can be established for certain kinds of products and make drying process comparable;
- direct observation allows to see defects of the process equipment immediately
- Infrared imaging allows to display product characteristics impacting the drying process by variations occurring due to pre-treatment processing of the products
- the mean temperature using infrared technique can be used for the management of the drying process;
- a limitation was the use of the technology for a macroscopic-granular sea-buckthorn layer which did not provide moisture transfer so well. The TUI did not show a typical gradient.

For the future, the research will focused on:

- modifying the LabView application using an output card in order to control the heater of the dryer;

- investigation related to the similarities between the pattern of temperature distribution and the shape changes in the process of different product slices.

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THE BIOCATALYTIC IMPACT OF LIPASE ON DIFFERENT TYPES OF FLOUR

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SUMMARY

This study presents the enzyme activity of lipase on different wheat flour types used in the baking industry. The following analysis were made: the fat content and the rheological characteristics of the flours and dough using the alveograph method. Lipase is an enzyme that catalyzes the hydrolysis of fats. It acts on nonpolar triglycerides or on polar and non-polar lipids which are present in the flour. The results of the investigation show the influence of lipase on the dough made from white flour, from whole flour and from brown flour. The influence of lipase can have positive or negative effect on the flours depending on the quantity of fats in the flour. The fat content of the flours is depending on the increase of the extraction rate. If the flour has a low fat content then the lipase improves the rheological characteristics of the flours and the finished product is presented with a higher volume and a better structure and porosity of the crumb. If the flour has a high content of fat then using lipase lead to a soapy taste in the finished product due the esterification of fatty acids released by lipolytic enzymes. Moreover the lipase that is not entirely degraded in the technological process can cause an increase in the acidity of the product and the discoloration of the crumb.

Key words: lipase, white flour, whole flour, brown flour, fat, alveograph method

INTRODUCTION

Bread is the most comun traditional food product in the entire world. It has a high nutritive value due to the content of easily retainable sugars, lipids and proteins. Flour is the primary ingredient in bread. The type of flour used will determine the quality of the bread. White flour typically has a high protein content and is capable of producing breads of

excellent quality. Whole flour is milled from the whole grain. It contains all of the bran and germ from the wheat grain. Because it contains the germ and bran, it retains vital nutrients. It needs to be used fresh, and stored properly as it gets rancid quickly due to the high fat content from the wheat germ. Typical protein levels range from 11.5%-14.0% and most whole flours are enriched. Brown flour is flour that contains about 80-90% of the wheat kernel, with some of the bran removed. The fat content of the flours is depending on the increase of the extraction rate, therefore the white flour has the lowest fat content followed by the brown flour and the whole flour.

By action of lipolytic enzymes, such as lipase, natural lipids from flour undergo hydrolytic changes. Lipase catalyses the hydrolysis of triglycerides into di- and monoglycerides, and ultimately into glycerol and free fatty acids. The di- and monoglycerides, as well as glycerol have stabilising function of oil-water emulsions, such as emulsifiers [1].

The addition of lipases modifies the natural flour lipids so they become better at stabilizing the dough. This ensures a more stable dough in case of over-fermentation, a larger loaf volume, and significantly improved crumb structure. Because of the more uniform and smaller crumb cells, the crumb texture is silkier and the crumb colour appears to be whiter. It also reduces the need for addition of emulsifiers that otherwise are commonly added to dough in order to stabilise it. Lipase can be successfully used in the place of chemical additives for synthesis.

METHODS

Samples preparation

Research has been conducted on various samples of wheat flour (white, whole and brown) mixed with salt, water, yeast and lipase enzymes.

The enzyme preparation used is:

ALPHAMALT LPX – enzyme preparation which contains lipase enzyme; dose: 0.2-5g/100kg flour; description: improves dough stability and increases the loaf volume (Muhlenchemie, Germany)

Each sample is mixed in a laboratory mixer 15 min to form dough. The amount of water was adjusted according to the water absorption capacity of flour. The water absorption process starts and the formation of the dough takes place by the transfer of the proteic content characteristics into the gluten chain. The fermentation represents a complex enzymatic process, specially of amylolytic hydrolysis of the carbon hydrates and of gluten proteolysis. [2]

The first three dough samples M1, M2 and M3 were prepared from each flour type containing 95% flour, 1.7% salt, 1.7% yeast and do not have any enzymes.

The next three samples F1, F2 and F3 were prepared from each flour type containing 95% flour, 1.7% salt, 1.7% yeast and 3g/100kg enzymes preparation which contain lipase.

Each dough sample is divided in five circular consecutive dough patties which are rested 20 min in the alveograph in a temperature-regulated compartment at 25 °C. Each dough patty is tested individually and the result is the average of the five dough patties.

Methods of analysis

The fat content of each dough sample was determined with Soxhlet method. Soxhlet method is based on repeated extraction with ethyl ether or petroleum ether of the fat substances in the sample, followed by removal of solvent and weighing oily residue obtained.

The analysis of the rheological characteristics of the dough was obtained by alveographic method. The alveographic method relies on measuring the resistance to biaxial stretch under air pressure of a dough sample prepared in standard conditions. The dough patty is placed on the alveograph, which blows air into it. The dough patty expands into a bubble that eventually breaks. The pressure inside the bubble is recorded as a curve on graph paper. The alveograph determines the gluten strength of dough by measuring the force required to blow and break a bubble of dough. The results include P Value, L Value, and W Value. Stronger dough requires more force to blow and break the bubble (higher P value). A bigger bubble means the dough can stretch to a very thin membrane before breaking. A bigger bubble indicates the dough has higher extensibility; that is, its ability to stretch before breaking (L value). A bigger bubble requires more force and will have a greater area under the curve (W value).

From the alveogram the following indicators were obtained:

- P Value is the force required to blow the bubble of dough. It is indicated by the maximum height of the curve and is expressed in millimeters (mm). It is also known as the viscosity or the value of maximum pressure that is in relationship to the resistance of the deforming dough (mm H₂O)
- L Value is the extensibility of the dough before the bubble breaks. It is indicated by the length of the curve that begins from the origin until the perpendicular point that corresponds to decreasing pressure due to rupture of air bubble and is expressed in millimeters (mm).
- G Value is the expansion index G being the average of the expansion index on the graphic of cellules and corresponds to breaking the abscise L, $G = 2.226L$, where L – air volume (cm³) used to stretch the dough under bubble form.
- P/L Ratio is the balance between dough strength and extensibility. It is the rapport of configuration of the curve.
- W Value is the area under the curve. It is a combination of dough strength (P value) and extensibility (L value) and is expressed in joules. It represents the action of deformation of the dough, based on a gram of dough, evaluated at 10×10^{-4} joule, calculated as follows: $W = 1.32 \times (V/L) \times S$, where V- air volume in mm³; L- the average abscise at breaking point in mm; S- surface of the curve, cm².
- Ie – elasticity index, represents the rapport between the measured pressures, expressed in mm H₂O to form bubbles after the insufflations of 200 cm³ of air in dough form, that correspond to a length L of 40 mm or an index of expansion G from 14,1 and the maximum of the curve P: $Ie\% = P_{200}/P_{max}$. [3]

RESULTS AND DISCUSSION

Soxhlet method

The results regarding the fat content of the dough samples are presented in the Table 1. As it can be seen the fat content varies with the flour type. The dough sample M3 (dough from whole flour without enzyme) has the highest fat content. After the addition of lipase the fat content decreased in all samples F1, F2 and F3 suggesting that lipase converts non-polar lipids into diglycerides and monoglycerides. The addition of lipases modifies the natural flour lipids so they become better at stabilizing the dough. This ensures a more stable dough in case of over-fermentation, a larger loaf volume, and significantly improved crumb structure. Because of the more uniform and smaller crumb cells, the crumb texture is silkier and the crumb colour appears to be whiter. It also reduces the need for addition of emulsifiers that otherwise are commonly added to dough in order to stabilise it.

Table 1 The fat content of the different dough samples

Sample	Lipides (%)
M1 (dough from white flour without enzyme)	1.1
M2 (dough from brown flour without enzyme)	1.4
M3 (dough from whole flour without enzyme)	1.8
F1 (dough from white flour with lipase)	0.6
F2 (dough from brown flour with lipase)	0.8
F3 (dough from whole flour with lipase)	1

Alvographic method

The dough samples alveograms are represented in Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5 and Fig. 6. Each dough sample alveogram shows the five dough patties tested (marked with different colors) and the parameters registered at the testing moment. The results of the samples are represented by the average value obtained from the values of the dough patties tests for each dough sample.

In Fig. 1, Fig. 2 and Fig. 3 the dough samples M1, M2, M3 represent the dough samples prepared from each type of flour (white flour, brown flour and whole flour) that do not contain any enzymes. These three samples are considered the blank sample.

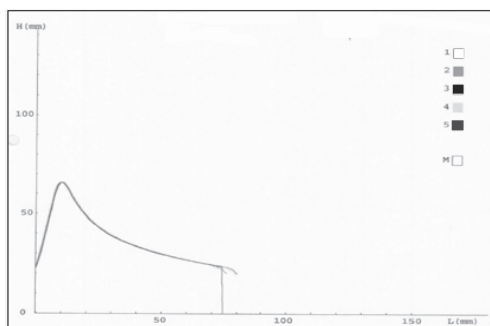
The alveogram's characteristics for flour used for bread have the following values: $P = [65 - 75\text{mm}]$, $L = [130 - 150\text{mm}]$, $G = [20 - 30]$, $P/L = [0,5 - 0,6]$ and $W > 180 \times 10^{-4}\text{J}$.

If we compare all three dough samples M1, M2 and M3 with the standard values we can notice that they do not have the proper rheological characteristics used for bread. But if we make a comparison between each sample we can see that the best rheological characteristics are presented in sample M1 (dough from white flour without enzyme) from Fig. 1. We can notice that the resistance of the deforming dough (P_{M1}) and the balance between dough strength and extensibility (P/L_{M1} ratio) are lower than the other samples.

The values regarding the dough extensibility (L_{M1}) are higher with 11mm than the M2 and with 18mm than M3. The expansion index (G_{M1}) is higher with 1.5 than G_{M2} and with 2.5 than G_{M3} . The total quantity of absorbed energy during the dough deformation (W_{M1}) is also higher than the M2 and M3. Although the dough from sample M1 is very resistant to stretch and does not easily brake it has the closes values to the standard values of the rheological characteristics in comparison with the other two samples M2 and M3. The worse values of the rheological characteristics are presented in dough sample M3 (dough from whole flour without enzyme) as we can see in Fig. 3. The resistance to deformation dough (P_{M3}) has the highest value compared to P_{M1} and P_{M2} and the dough extensibility (L_{M3}) is the lowest. The P/L_{M3} ratio is 1.44 which is higher with 0.48 than P/L_{M1} and with 0.33 then P/L_{M2} . The expansion index (G_{M3}) is lower by 2.5 than sample M1 and by 1 than M2. These parameters suggest that the three samples are not suitable for bread making.

In Fig. 4, Fig. 5 and Fig. 6 are represented the alveograms of the dough samples F1 (dough from white flour with lipase), F2 (dough from brown flour with lipase) and F3 (dough from whole flour with lipase) which contain the addition of lipase.

In comparison with the blank samples M1, M2 and M3 there is a significant improvement of the rheological characteristics in all types of flour suggesting that the addition of lipase helps in controlling the fat content which leads to a good handling in the manufacturing process and a better quality of the finish product. In Fig. 4 we can notice that the dough strength (P_{F1}) decreased with 3 mmH₂O compared to P_{M1} . Looking at the extensibility characteristics and the absorbed energy during the dough deformation we can see, obviously, the dough quality improvements. The P/L_{F1} value is lower because of the decreased dough strength and increase of the dough extensibility. These results suggest that the dough samples F1 (dough from white flour with lipase) can be considered for manufacturing of bread. In Fig. 5 the dough sample F2 (dough from brown flour with lipase), presents a reduction in the dough strength (P_{F2}) with 13 mmH₂O compared to P_{M2} . The absorbed energy during the dough deformation (W_{F2}) has increased with 26×10^{-4} J and the P/L_{FA} ratio was reduce to 0.60. In Fig. 6 the dough sample F3 (dough from whole flour with lipase), presents a reduction in the dough strength (P_{F3}) with 18 mmH₂O compared to P_{M3} . The absorbed energy during the dough deformation (W_{F3}) has increased to 169×10^{-4} J and the P/L_{F3} ratio was reduced to 0.80. There is a small increase of the extensibility characteristics and of the elasticity index (Ie_{F3}) compared to (Ie_{M3}).



Results

$$P_{M1} = 71 \text{ mmH}_2\text{O}$$

$$L_{M1} = 75 \text{ mm}$$

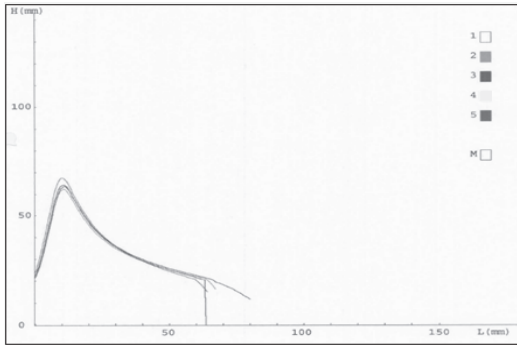
$$G_{M1} = 19.3$$

$$W_{M1} = 183 \times 10^{-4} \text{ J}$$

$$P/L_{M1} = 0.96$$

$$Ie_{M1} = 52.0 \%$$

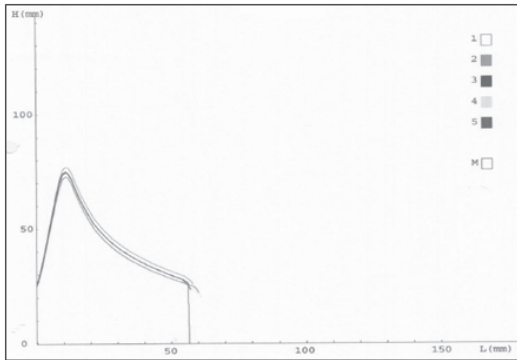
Fig. 1 Sample M1 (dough from white flour without enzyme) alveogram



Results

$P_{M2} = 72 \text{ mmH}_2\text{O}$
 $L_{M2} = 64 \text{ mm}$
 $G_{M2} = 17.8$
 $W_{M2} = 152 \times 10^{-4} \text{ J}$
 $P/L_{M2} = 1.11$
 $Ie_{M2} = 46.3 \%$

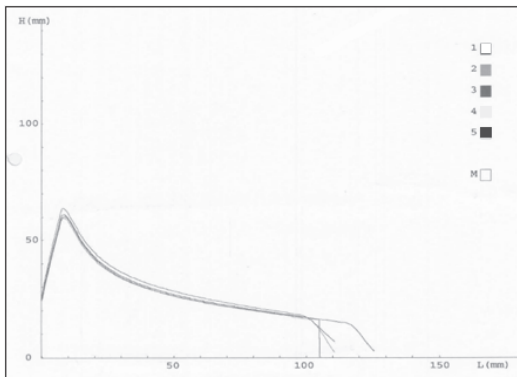
Fig. 2 Sample M2 (dough from brown flour without enzyme) alveogram



Results

$P_{M3} = 82 \text{ mmH}_2\text{O}$
 $L_{M3} = 57 \text{ mm}$
 $G_{M3} = 16.8$
 $W_{M3} = 166 \times 10^{-4} \text{ J}$
 $P/L_{M3} = 1.44$
 $Ie_{M3} = 47.3 \%$

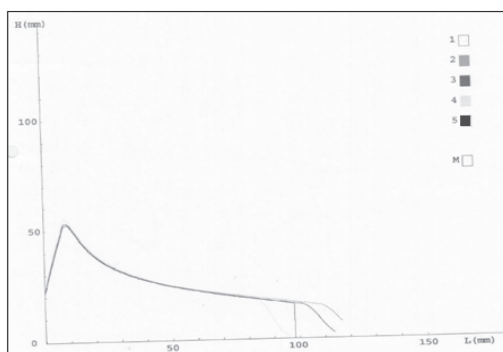
Fig. 3 Sample M3 (dough from whole flour without enzyme) alveogram



Results

$P_{F1} = 68 \text{ mmH}_2\text{O}$
 $L_{F1} = 106 \text{ mm}$
 $G_{F1} = 22.9$
 $W_{F1} = 206 \times 10^{-4} \text{ J}$
 $P/L_{F1} = 0.64$
 $Ie_{F1} = 49,4 \%$

Fig. 4 Sample F1 (dough from white flour with lipase) alveogram



Results

$$P_{F2} = 59 \text{ mmH}_2\text{O}$$

$$L_{F2} = 99 \text{ mm}$$

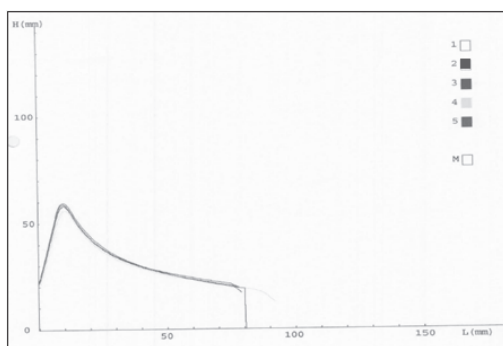
$$G_{F2} = 22.1$$

$$W_{F2} = 178 \times 10^{-4} \text{ J}$$

$$P/L_{F2} = 0.60$$

$$Ie_{F2} = 51.5 \%$$

Fig. 5 Sample F2 (dough from brown flour with lipase) alveogram



Results

$$P_{F3} = 64 \text{ mmH}_2\text{O}$$

$$L_{F3} = 80 \text{ mm}$$

$$G_{F3} = 19.9$$

$$W_{F3} = 169 \times 10^{-4} \text{ J}$$

$$P/L_{F3} = 0.80$$

$$Ie_{F3} = 51.0 \%$$

Fig. 6 Sample F3 (dough from whole flour with lipase) alveogram

In Tabel 2 there are presented the characteristics of dough samples obtained by alveographic method.

Table 2 Alveograph results of the different dough samples

Sample	M1 (dough from white flour without enzyme)	M2 (dough from brown flour without enzyme)	M3 (dough from whole flour without enzyme)	F1 (dough from white flour with lipase)	F2 (dough from brown flour with lipase)	F3 (dough from whole flour with lipase)
P(mmH₂O)	71	72	82	68	59	64
L(mm)	75	64	57	106	99	80
G	19.3	17.8	16.8	22.9	22.1	19.9
W(10⁻⁴J)	183	152	166	206	178	169
P/L	0.96	1.11	1.44	0.64	0.60	0.80
Ie(%)	52.0	46.3	47.3	49,4	51.5	51.0

The dough sample M3 (dough from whole flour without enzyme) has the highest values for the resistance of the deforming dough (P_{M3}) and the balance between dough strength and extensibility (P/L_{M3} ratio) and the lowest values for dough extensibility (L_{M3}) compared to the other samples. This indicators were improved when adding the lipase as it can be seen in sample F3 (dough from whole flour with lipase) which shows that the dough resistance to deformation (P_{F3}) and the P/L_{F3} ratio decreased significantly. Similar improvements are shown in F2 (dough from brown flour with lipase) compared to dough sample M2.

Although these samples show improvement the lipase that is not entirely degraded in the technological process causes an increase in the acidity of the product and the discoloration of the core. Also we can see that the best characteristics are in sample F1 (dough from white flour with lipase) due to a significant decrease for the dough strength (P_{F1}) and an increase of $23 \times 10^{-4} \text{J}$ in the absorbed energy during the dough deformation (W_{F1}) compared to M1 (dough from white flour without enzyme) which suggest that addition of lipase helps strengthen the gluten network resulting an increase in loaf volume.

If we observe only the dough samples that have lipase addition we can notice that the best rheological characteristics are in sample F1 (dough from white flour with lipase) because it shows better extensibility and elasticity characteristics which leads to a good handling in the manufacturing process. If the flour has a low fat content as in F1 (dough from white flour with lipase) then the lipase improves the rheological characteristics of the flours and the finished product is presented with a higher volume and a better structure and porosity of the core. The dough samples F2 and F3 they show improvements in the dough strength and the extensibility characteristics but they do not achieve the standard values for bread making. Lipase hydrolyze triglyceride esters and produce mono- or di-glycerides, glycerol and free fatty acids. Lipases strengthen dough stability and increase bread volume, texture and shelf-life. Flour lipids play an important technological role because they interact with proteins and starch in dough, influencing the rheological properties of dough, bread quality and its freshness.

CONCLUSIONS

The additive actions of complex enzymes as ameliorator on flour have positive effects on the rheological characteristics of dough. The technological characteristics of the flour and the nutritive value of the bread are characterized by the following variables: initial volume, fermentation time, flexibility, the dough condition to fermentation, water retention, maximum resistance, extensibility, final rise to baking, final volume of the bread, nutritive value, and energy value. In order to improve these variables, different additives and substances are used in the bread manufacture, some of these being native components of the flour.

The alveograph test provides results that are common specifications used by flour millers and processors to ensure a more consistent process and product. The alveograph is well suited for measuring the dough characteristics and what we can notice is that best characteristics are in sample F1 (dough from white flour with lipase) due to a significant decrease for the dough strength (P_{F1}) and an increase in the absorbed energy during the dough deformation (W_{F1}) which suggest that by using lipase in bread making, the effects on baked products were visible in terms of loaf volume increasing, the freshness preserving,

as well as the crumb properties improvement. If the flour has a high content of fat then using lipase lead to a soapy taste in the finished product due the esterification of fatty acids released by lipolytic enzymes. Moreover the lipase that is not entirely degraded in the technological process can cause an increase in the acidity of the product and the discoloration of the core. In this way the results related rheological improving of dough properties could be argumentation in view of lipids significance and linkages with the main compounds, gluten protein and starch.

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IDENTIFICATION OF *SACCHAROMYCES CEREVISIAE* WINE YEASTS ISOLATED FROM LOCAL AREA

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SUMMARY

The aims of this paper is to study the environmental influences in vinification process by use of selected yeast strains isolated from local area, Apoldu de Jos (Romania) vineyard and analyze their ability to potentiate a higher amount of flavor compounds by alcoholic fermentation of the grape must rose Traminer. Traditionally, wine has been made by spontaneous fermentation of grape must under the influence of existing yeast on grapes, in soil, vineyard. Saccharomyces cerevisiae yeast under suitable temperature and anaerobiosis decompose carbohydrates of grape must resulting carbon dioxide, ethylic alcohol and secondary compounds. The number of the yeast cell of spontaneous fermentation does not exceed 10^4 cells / mL, the lag phase, whereas in the guided fermentation by the inoculum with culture yeasts the number reached about 5×10^6 cells / mL.

Nowadays these fermentations are carefully monitored in order to obtain high quality wines with specifies flavors, aromas enhanced with selected yeasts from the area of local wine, isolated yeasts from the best years in terms of grapes quality. In this paper the alcoholic fermentation of grape must was conducted in laboratory micro wine system, variety selected as rose Traminer. Strains selection was done after the identification and quantification of esters and carbonyl compounds by GC-MS methods, the comparison is performed with Saccharomyces cerevisiae yeast culture commercial Varioferm Siha. Saccharomyces cerevisiae strain SCAJ 212 presented best biotechnological properties, so it was selected for industrial multiplication (for insure weak influences from Saccharomyces cerevisiae).

Key words: *Saccharomyces cerevisiae, fermentation, GC-MS, esters, carbonyl compound*

INTRODUCTION

Fermentation of grape must is a very complex process that occurs under the influence of microorganisms existing in his microbiota, bacteria, yeasts and filamentous fungi [3], [1]. Predominant yeast during the maturation and in the first hours of the fermentation are *Kloeckera* species, *Candida*, *Pichia*, *Cryptococcus*, *Debaryomyces*, *Hansenula*, *Kluyveromyces*, *Rhodotorula* [6], [3]. The *Saccharomyces cerevisiae* and *Saccharomyces bayanus* species reduce number of microorganisms in this stage, that depend by a number of environmental factors such as rainfall, temperature, use of fungicides, etc. In the first five hours of fermentation, predominant yeasts are from *Hanseniaspora* / *Kloeckera* species.

After a period of 20-24 hours is multiplied in accordance with a spontaneous fermentation of the *Saccharomyces cerevisiae* yeast, which causes ethylic alcohol. In the next phase, the exponential multiplication of the number of cells yeast reached 107-108 cells/ml, the period is three to six days, depending by the temperature applied to the fermentation, the nutrients in the medium, and the concentration of oxygen [2], [5], [7].

Stationary phase lasts between two and ten days, at which time the yeast consumes the nutrients in the medium, they no longer replicate because there is a feed gap, followed by a decline phase. In this step accumulates alcohol in large amounts, making it toxic to the yeast cells, and eventually resulting in their death. Quality alcoholic fermentation involves consuming of all the quantity of sugars from must by the yeast population and turn them into ethylic alcohol and carbon dioxide [9]. Wine yeast, particularly *Saccharomyces cerevisiae* the lead to potentiation and build flavors in wines. The main compounds responsible for the aroma of a wine are presented in Table 1. In order to preserve the typology of the wine is recommended to use the wine yeast selected.

In order to preserve the of the wine is recommended to use the wine yeast selected.

METHODS

Materials for experiments:

- Grape must Rose Traminer, from Apoldu de Jos vineyard, autoclaved for 15 minutes / 110°C. *Saccharomyces cerevisiae* Siha varioferm commercial wine yeast 20g/hl (www.begerow.com, Germany) SCSV code
- selected wine yeast (Centre for Research in Biotechnology and Food Engineers) isolated from Apoldu de Jos vineyard SCAJ code 314.
- selected wine yeast (Centre for Research in Biotechnology and Food Engineers) isolated from Apoldu de Jos vineyard SCAJ code 212
- selected wine yeast (Centre for Research in Biotechnology and Food Engineers) isolated from Apoldu de Jos vineyard SCAJ code 18.

Fermentation temperature: 18°C for 21 days

Was monitored quantitative accumulation of esters and carbonyl compounds in the resulting wines. Identification and quantification was performed by the method described Stegăruș (2014) GC-MS [8].

Table 1 The main flavor compounds in wine [4], [10]

	Compounds	Concentration in Wine, [mg/l]	Flavor perceived
Volatile fatty acids	Acetic acid	150-900	Sour
	Propionic acid	traces	Rancid
	butyric acid	traces	bitter
	hexanoic acid	Up to 37	sour, rancid, cheese
	octanoic acid	Up to 41	oily, rancid, sweet, buttery
	decanoic acid	Up to 54	unpleasant, rancid, bitter, phenolic
Higher alcohols	propanol	9-68	intense
	butanol	0,5-8,5	oil
	2-methyl-1-butanol	15-150	marzipan
	acid isobutyl	9-28	alcoholic
	isoamyl alcohol	45-490	marzipan
	hexanol	0,3-12	fresh grass
Esters	2-phenylethanol	10-180	roses, floral
	Isoamyl acetate	0,03-8,1	bananas, pears
	2-phenylethyl acetate	0,01-4,5	roses, honey, fruit, floral
	Ethyl acetate	26-180	nail polish, fruit
	Propyl acetate	Up to 2,3	plum
	Butyl acetate	Up to 2,7	pears
	Ethyl butyrate	Up to 3,9	pineapple
	Ethyl caproate	Up to 1,4	apple
	Ethyl caprylate	Up to 0,9	citrus
	Ethyl caprate	Up to 2,4	pineapple
	Ethyl cinnamate	Up to 1,1	fruits
	Isobutyl acetate	0,01-0,8	bananas
	Ethyl butanoat	0,01-1,8	floral, fruits
	Ethyl hexanoat	Up to 3,4	apple, banana, violet
	Ethyl octanoat	0,05-3,8	pineapple, pear
	Ethyl decanoat	Up to 2.1	floral
Carbonyl compounds	acetaldehyde	10-300	bitter, green pineapple
	benzaldehyde	0,003-4,1	bitter almonds
	benzaldehyde	0,05-5	fresh butter
Volatile phenolic compounds	4-vinylphenol	0-1,15	Medicinal
	4-vinyl guaiacol	0-0,496	smoke, vanilla
	4-ethylphenol	0-6,047	horse sweat
	4-ethyl guaiacol	0-1,561	smoke, vanilla
Sulphur compounds	hydrogen sulfide	Up to 0,080	rotten eggs
	Dimethyl disulfide	Up to 0,0016	boiled cabbage
	Diethyl disulfide	Up to 0,0008	garlic, burnt rubber
	methyl mercaptan	Up to 0,004	rotten eggs, cabbage
	ethyl mercaptan	Up to 0,0007	onion, rubber

RESULTS AND DISCUSSION

In this study, four strains of yeast used for fermentation, one commercial, the company Begerow-Germany and three local strains of yeast. Local strains were isolated from Apoldu de Jos vineries, which are the best biotechnological properties, selection is performed by specific oenological criteria previously tested. After alcoholic fermentation, resulted wines were tested to identify and quantification of flavor compounds (esters and carbonyl compounds). Chromatogram results are visible in Figure 1.

As shown in Figure 2 the amount esters identified by GC-MS after inoculation wine results from commercial yeast Begerow- German Company, the higher amount quantum is of 371,723mg / l. Traminer rose wines obtained from the inoculation yeast with the local yeast is an accumulation of esters as follows: SCAJ212 strain leads to an accumulation of esters 349,429mg / l, followed by SCAJ314 strain with 307,652mg / l, and the lowest value is found for an amount of SCAJ18 strain 297,216mg / l. Compared with the control yeast strain SCAJ212 isolated in Centre for Research in Biotechnology and Food Engineers lead to a higher accumulation of esters leading to its selection for commercial purposes.

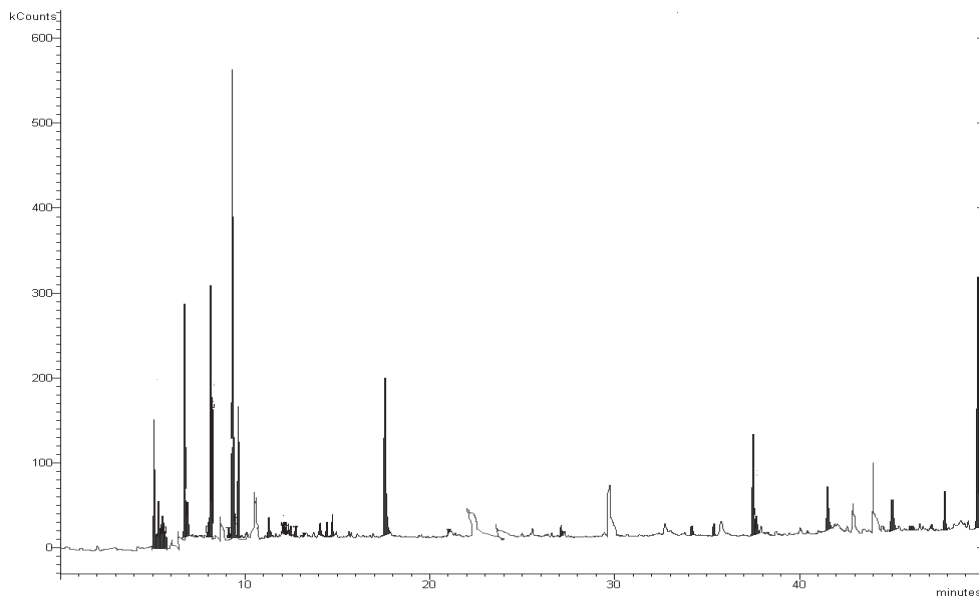


Figure 1 Chromatogram of aroma compounds resulting from the alcoholic fermentation of must rose Traminer with *Saccharomyces cerevisiae* yeast SCAJ 212

Regarding the accumulation of carbonyl compounds resulting values resulted in ranking yeast follows: strain SCAJ 212 has a rate of 218,187mg / l, commercial strain SCSV of 265,111mg / l, followed by isolate strain in laboratory SCAJ314 with an accumulation of 256,098 mg / l, and the last strain SCAJ 18 worth 237,997mg / l. In accumulation of carbonyl compounds can say that strain SCAJ 212 shows the lowest value regarding the commercial strain SCSV, the difference is 0.18%.

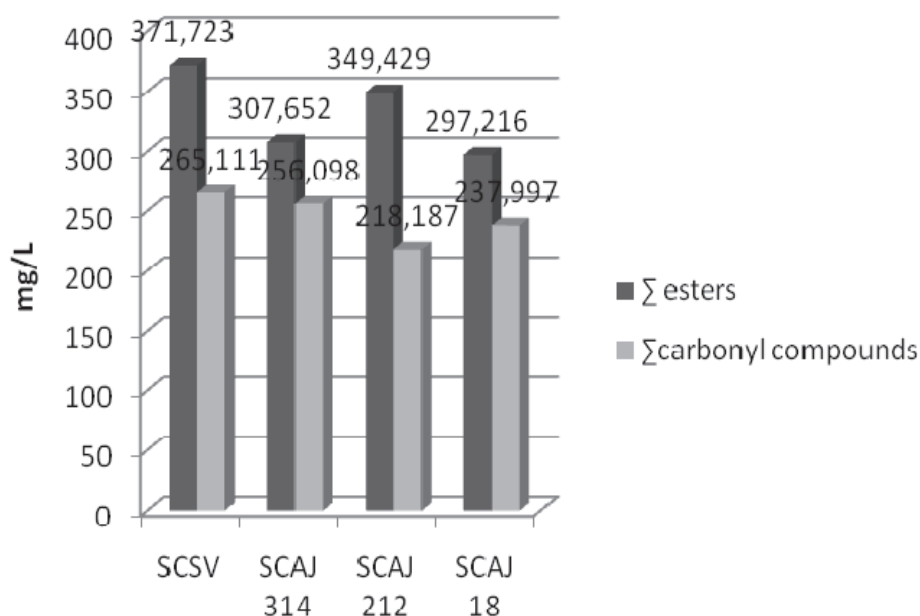


Figure 2 Quantification of aroma compounds in rose Traminer wines using selected yeasts

CONCLUSIONS

Commercial wine yeast SCSV lead to a higher accumulation of esters isolated from the local micro biota, but their biotechnological properties can be improved using natural methods. *Saccharomyces cerevisiae* yeast SCAJ 212 isolated in the laboratory showed a lower range of carbonyl compounds in compare with the *Saccharomyces cerevisiae* yeast SCSV so that they can be recommended and selected for multiplication.

Bitter notes lower conferred by these compounds lead to a balanced wine, harmonious, pleasant. Isolated wine yeast from indigenous micro biotic has qualities and can be used to obtain typical wine from APOLD area. Ester values obtained lead to the conclusion that they are significantly closer to those obtained by the alcoholic fermentation of *Saccharomyces cerevisiae* strains established commercial market, so SCAJ 212 strains were selected for industrial multiplication.

ACKNOWLEDGMENTS

This work was supported by the strategic grant POSDRU/159/1.5/S/133255, Project ID 133255 (2014), co-financed by the European Social Fund within the Sectorial Operational Program Human Resources Development 2007-2013

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EXPERT SYSTEM BASED CONTROL OF THE STARCH BIOCONVERSION PROCESS

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SUMMARY

In this paper, an expert system for starch enzymatic hydrolysis was developed in order to assists the industry at choosing technological solutions for the starch bioconversion. Process parameters are defined and the hydrolysis plant is designed. Practical results regarding the enzyme concentration at the obtaining of hydrolysis products with different degree of polymerization and different values of dextrose equivalent are presented. The structure resulted after normalization of tables in the database is described, together with tables reflecting the systems ontology. The expert system realized in this work provides support for the data storage and the introduction of new practical data generated by research, generation and storage of knowledge on the starch bioconversion.

Key words: *Expert system, starch, enzymatic hydrolysis, hydrolysis parameters*

INTRODUCTION

Starch is a key material to many food technologies; the starch enzymatic bioconversion is used to obtain glucose syrups, maltose syrups, maltodextrins, fructose syrups (Hobbs, 2009). In the last decades, the development of molecular biology and genetic engineering gave an increase of the number of enzymes used for starch bioconversion; depending on the enzyme/enzymes used and controlling the enzymatic reactions, the obtaining of products with known compositions and different properties is possible (Robyt, 2009).

The complex composition of starch bioconversion products, the large number of enzymes used and the difficulty of obtaining identical products requires the characterization of this bioprocess. The main manufacturers' task is to find the optimum combination of enzymes that allow the obtaining of hydrolysis products with defined compositions and properties. Many international research in this field are oriented on building models to

describe starch bioprocesses such as kinetic models (Komolprasert and Ofoli, 1991), iterative models (Wojciechowski et al., 2001), neural networks (Bryjak et al., 2000).

In order to solve this problem, the authors propose an original approach, namely the creation of an expert system (ES). ES is a program designed to solve problems which typically required considerable human expertise (O'Keefe and O'Leary, 1993). There are a lot of ESs in various applicative areas, as genetics, medicine, production planning or wastewater management (Liao, 2005), but no ES in the field of starch bioconversion was found in literature. (Mironescu and Mironescu, 2011) have designed an SE for starch bioconversion that enables the collection, analysis, ordering and storage of information generated from the starch hydrolysis: bioprocess, characterization of hydrolysis products and bioprocesses model building. This paper continues the previous work and shows the ES ontology, together with the main practical results used to build the expert system.

MATERIALS AND METHODS

Suspensions 40% of corn starch were used for all experiments. The quality of the hydrolysis process was assessed by determining the sugars composition (Degree of Polymerisation DP) as described in (Mironescu et al., 2007), namely the qualitative and quantitative analysis of DPs: DP1 (glucose), DP2 (maltose), DP3 (maltotriose), DP4 (maltotetraose) and DP $\geq$ 5 (compounds with higher molecular mass).

The enzymes used were:

- Termamyl 120 L and Liquezyme Supra for the stage of liquefaction;
- Optimalt BBA for the stage of saccharification at the obtaining of maltose syrups;
- Optidex L-400 for the stage of saccharification at the obtaining of glucose syrups; Dextrozyme for the stage of saccharification at the obtaining of dextrose syrups.

Factorial designs were used to identify the enzymes doses (Mironescu et al., 2011) (Mironescu and Mironescu, 2012). The enzymes quantities at the obtaining of:

- maltodextrins with DE = 20-24; DP $\geq$ 5 90-95%; DP1 0-2%
- maltose syrup with DE = 43-46; DP1 0-5%; DP2 43-46;
- maltose syrup with high hydrolysis degree and DE = 48-52; DP1 0-5%; DP2 48-52;
- maltose syrup with very high hydrolysis degree and DE > 52; DP1 0-5%; DP2 > 52;
- glucose syrup with low hydrolysis degree and DE = 25-38;
- glucose syrup with medium hydrolysis degree and DE = 39-58; DP1 10-30%;
- glucose syrup with high hydrolysis degree and DE = 59-65; DP1 30-40%;
- dextrose syrup with DE = 96-98; DP1 93-97%;
- dextrose syrup with DE = 79-97; DP1 96%

were obtained by practical experiments in the plant designed in Figure 1.

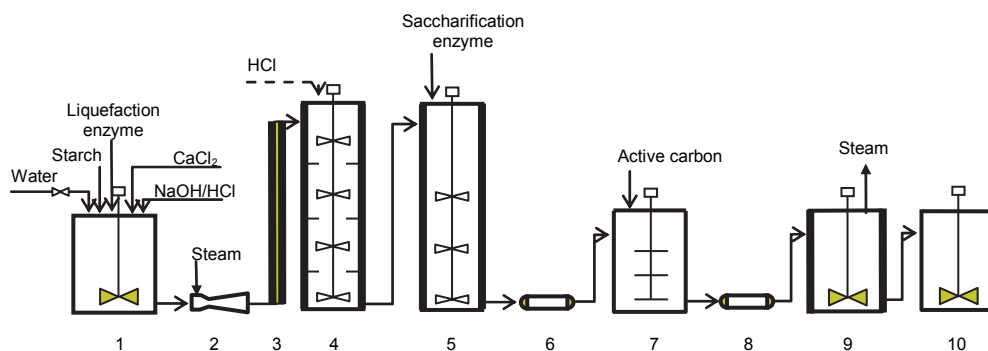


Figure 1 Plant used to obtain the hydrolysis products; 1: mixing vessel; 2: jet-cooker; 3: gelatinisation + preliminary liquefaction tubular reactor; 4: bioreactor for liquefaction; 5: bioreactor for saccharification; 6: filtration unit 1; 7: vessel for decolouration; 8: filtration unit 2; 9: concentration vessel; 10: storage vessel.

Starch slurry with 40% starch was first obtained, then chemicals for pH adjustment and calcium ions adjustment were added and finally the liquefaction enzyme was added in vessel 1 from Figure 1. The mix was very fast heated (seconds) with steam in the jet-cooker at 110 °C. The preliminary stage of gelatinisation + preliminary liquefaction was realised by thermal treatment for 2 minutes at 107°C in the tubular reactor 3. Liquefaction was realised in the bioreactor 4, where HCl was added at the end of liquefaction time to inactivate the liquefaction enzyme; saccharification took place in the bioreactor 5 both bioreactors have jacket to maintain the desired temperature and stirring system because the hydrolysis products are very viscous, especially the starch after gelatinisation. The saccharification enzyme was thermal inactivated at 80°C.

The syrups obtained were filtered, decoloured and concentrated.

For the obtaining of maltodextrins, maltose and glucose syrups, the optimal enzyme concentrations for liquefaction were found for two situations:

- a) without economy of Calcium ions, by using Termamyl 120L as liquefaction enzyme and the working parameters: liquefaction time 2 h, pH 6.2, Calcium ions 70 ppm, temperature 85°C;
- b) with economy of Calcium ions, by using Liquozyme Supra as liquefaction enzyme and the working parameters: liquefaction time 2 h, pH 5.5, Calcium ions 5 ppm, temperature 85°C.

For the obtaining of maltose syrups, the optimal concentrations of the enzyme Optimalt BBA were found, the other working parameters being maintained at the same values: saccharification time 48 h, pH 4.5, temperature 60°C.

For the obtaining of glucose syrups, the optimal concentrations of the enzyme Optidex L-400 were found, the other working parameters being maintained at the same values: saccharification time 48 h, pH 4.5, temperature 60°C.

For the obtaining of dextrose syrups, the optimal concentrations of the enzyme Dextrozyme were found, the other working parameters being maintained at the same values: saccharification time 70 h, pH 4.5, temperature 60°C.

To support all levels of ES design, a three tier architecture was developed, where: PostgreSQL was used as a backend; Linux Debian 5.0. for AMD64 architecture was the operating system; Postgres Plus Standard Server distribution from Enterprise DB for Linux x86-64 was used for the database management system DBMS (Mironescu and Mironescu, 2011). In the intermediary layer, Python language was chosen as working environment. Applications in Python were developed to collect the data from each experiment and to expose them as web services through OPC XML DA, in order to create a unitary interface. For metadata description, a semantic web platform with Resource Description Framework RDF support was used. For the development of the interface layer, the Seaside environment was chosen (Mironescu and Mironescu, 2011).

The ES functional scheme is presented in (Mironescu and Mironescu, 2011). Shortly, the ontology has been defined by introducing a specific vocabulary; classes representing raw materials and all possible products (with description) were defined in OWL and stored through the D2RQ platform; the user interfaces were automatically created using the Magritte framework in Seaside / Pharo. Experimental results have been stored and held as fact basis. The fact base can be interrogated by using the web interface of ES. The web interface transfers the user selections to the interrogation engine which transforms them in the interrogations corresponding to the fact base. The first interrogation is made implicitly by ES in order to determine the products for which knowledge exists. Using the results of this interrogation, the list from which the user can choose the product is generated. For each stage, ES generates an interface with the interrogation input parameters and the possibilities from which the user has to choose (Mironescu and Mironescu, 2012).

RESULTS AND DISCUSSION

The optimal doses of enzymes found experimentally are presented in Table 1.

Ontology is a set of concepts within a domain and the relationships between these concepts in a form that can be used by the expert system (ES) for cataloguing and processing of information it contains (Giarratano and Riley, 2005). Central term of ontology is the *product*, which is what we want to achieve at the end of the process developed by SE. Each product is associated with a process consisting of *steps*. Each stage is characterized by technological *parameters* specific to them. Each technological *parameter* may take one or more *values*.

A search in the ES is based on a *product* for which ES is proposing *steps* and variations of technological *parameters*. The user chooses combinations of such parameters, and the system gives the values of other parameters, so the process is completely defined.

Due to this ontology, the database to store facts based on facts was structured. The data in Table 1 were subsequently placed in the database. For this, they were normalized to avoid errors at updating and to ensure the system extensibility. The resulting structure after this normalization is shown in Figure 2.

Table 1 Enzymes concentration for the production of different starch hydrolysis products

No.	Final product	Stage	Enzymes used	Enzyme conc., g/kg dry substance
1.	Maltodextrins DE = 20-24; DP $\geq$ 5 90-95%; DP1 0-2%	Liquefaction	Termamyl 120L	0.4
			Liquozyme Supra	1.2
2.	Maltose syrup DE = 43-46; DP1 0-5%; DP2 43-46	Liquefaction	Termamyl 120L	0.3
		Saccharification	Optimalt BBA	0.3
		Liquefaction	Liquozyme Supra	0.5
		Saccharification	Optimalt BBA	0.4
3.	Maltose syrup with high hydrolysis degree DE = 48-52; DP1 0-5%; DP2 48-52	Liquefaction	Termamyl 120L	0.3
		Saccharification	Optimalt BBA	0.6
		Liquefaction	Liquozyme Supra	0.7
		Saccharification	Optimalt BBA	0.6
4.	Maltose syrup with very high hydrolysis degree. DE = 48-52; DP1 0-5%; DP2 48-52	Liquefaction	Termamyl 120L	0.3
		Saccharification	Optimalt BBA	0.8
		Liquefaction	Liquozyme Supra	1
		Saccharification	Optimalt BBA	0.8
5.	Glucose syrup with low hydrolysis degree DE = 25-38;	Liquefaction	Termamyl 120L Liquozyme Supra	1.2-1.3
		Saccharification	Optidex L-400	0.1-0.2
6.	Glucose syrup with medium hydrolysis degree. DE = 39-58; DP1 10-30%	Liquefaction	Termamyl 120L Liquozyme Supra	1.2-1.3
		Saccharification	Optidex L-400	0.4
7.	Glucose syrup with high hydrolysis degree DE = 59-65; DP1 30-40%	Liquefaction	Termamyl 120L Liquozyme Supra	1.2-1.3
		Saccharification	Optidex L-400	0.5-0.6
8.	Dextrose syrup DE = 79-97; DP1 60-94%	Liquefaction	Termamyl 120L Liquozyme Supra	1.2-1.3
		Saccharification	Optidex L-400	0.6-0.8
9.	Dextrose syrup DE = 96-98; DP1 93-97%	Liquefaction	Termamyl 120L Liquozyme Supra	1.2-1.3
		Saccharification	Dextrozyme	0.6-0.8
10.	Dextrose syrup DE = 79-97; DP1 96%	Liquefaction	Termamyl 120L Liquozyme Supra	1.2-1.3
		Saccharification	Dextrozyme	0.8-1

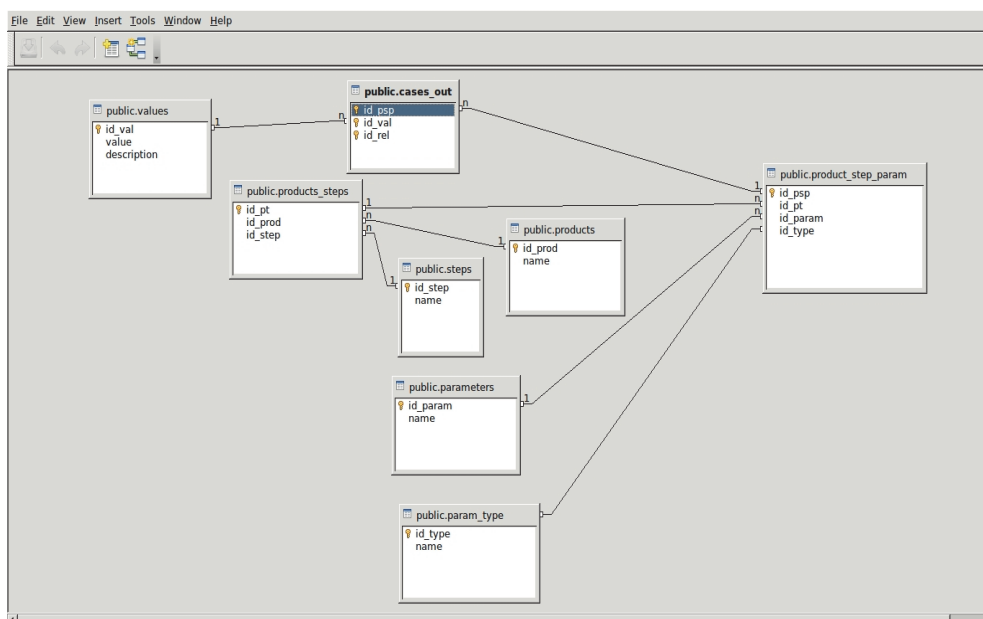


Figure 2 The structure resulted from the normalization of data tables

Table *product* (Figure 3a) contains the elements that define the product: name and a list of features that allow the user's selection of expert system. Table *steps* (Figure 3b) contains the name of technological steps. The relationship 'many to many' existing between products and stages - one stage may occur for several products and a product can be obtained in several stages - is implemented by an additional table *product_step* which associates to each product the appropriate technological steps.

File Edit View Insert Tools Window Help	
id_prod	name
1	Maltodextrins
2	Maltose syrup with high hydrolysis degree
3	Maltose syrup with very high hydrolysis degree
5	Glucose syrup with small hydrolysis degree
6	Glucose syrup with middle hydrolysis degree
7	Glucose syrup with high hydrolysis degree
4	Maltose syrup
8	Dextrose syrup
Record 1	of 8

a

File Edit View Insert Tools Window Help	
id_step	name
1	Gelatinisation & preliminary liquefaction
2	Liquefaction
3	Saccharification
Record 1	of 3

b

Figure 3 Tables *product* (a) (containing the products name and a list of features for each defined product) and *steps* (b) containing the names of technological steps

Table *parameters* in Figure 4a contains the name of the parameters that describe each step of the technological process. The relationship 'more to several' associating to each

technological step the parameters relevant to its management was implemented by table *product_step_param*.

These tables reflect the ontology system and any change reflects a change in their associated ontology changes which predispose them to rare and usually as insertion (ontology enrichment). Table *values* (Figure 4b) contains values of technological parameters (which are known, they are taken from the technology) for the process optimization.

Figure 4 consists of two screenshots of software interfaces. Screenshot (a) shows a table titled 'parameters' with two columns: 'id_param' and 'name'. The table contains 12 rows of data. Screenshot (b) shows a table titled 'values' with two columns: 'id_val' and 'value'. The table contains 32 rows of data.

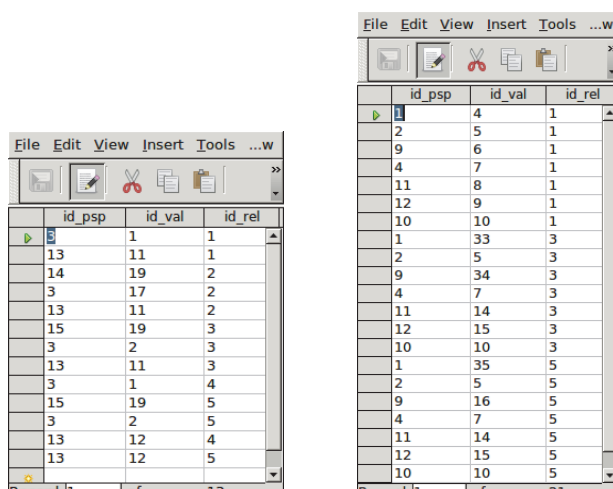
id_param	name
6	Enzyme concentration
2	Calcium ions
3	Time
1	Temperature
5	Enzyme
8	pH
7	DE of final product
9	%DP>5
10	%DP1
11	%DP2
12	Enzyme economy
	Economy of Calcium ions

id_val	value
1	Termamyl 120L
2	Liquozyme Supra
3	Dextrozyme
4	1-2 min
7	2 h
9	70 ppm
11	20-24
12	18-20
13	11 min
15	5 ppm
17	Termamyl 2X
18	Optimalt BBA
19	yes
20	Optidex L-400
21	20-38
22	43-46
23	39-58
24	10-30
25	59-65
26	30-40
27	79-97
28	60-94
29	Dextrozyme
30	96-98
31	93-97
32	96

Figure 4 Tables *parameters* (a) and *values* (b) containing the values of technological parameters

The values are associated to the parameters with the connection tables *cases_in* and *cases_out* (Figures 5 a and b). These implement an appropriate relationship corresponding to a *case* which is the combination of parameters optimal values for each stage of a given product. Separation of the input parameters (for which values are chosen by the user) and output parameters (for which values are given by the system response) was performed for the query performance.

Each case resulted from experimental work considered as optimal can be introduced to improve the knowledge base of the ES by filling the tables described above. The user can introduce facts for existing product or for a new product. If the product is new, the user must add it to indicate the name and characteristics. Also, he has to associate the technological stages to the product, using those defined in the system or entering new stages. If the product already exists, the user selects it from the list provided by the system and then specifies the parameters value for each step from practice.



a

b

Figure 5 Connections tables: a) *cases_in*; b) *cases_out*

The system is flexible enough to accept any combination of input parameters, if the practice requires.

CONCLUSIONS

The experimental work has proven that the enzyme concentration is a very important factor influencing the syrups characteristics. The use of controlled doses of enzymes allows the obtaining of syrups with different values of DE and different composition (DPs). The knowledge about doses mixes and operative steps, accumulated by performing tests according to an experimental design can be efficiently reused if it's properly stored in the ES.

The experimental plant has proven itself as adequately designed. The correlation between the process parameters and the resulted products are well captured and can be easy scaled up to the industrial production.

The defined ontology is adequate and sufficient for the acquisition, storage and retrieval of the knowledge related to the starch enzymatic hydrolysis.

The chosen design confers flexibility, extensibility and robustness to the expert system for starch enzymatic hydrolysis. Because everything is described in the core database extending the ontology is performed by inserting new lines in corresponding tables and the corresponding user interfaces are automatically adapted. Because the data base is normalised common update errors are avoided in the knowledge acquisition from the process. Also extending the functionality is performed by adding tables without modifying the existing ones.

ACKNOWLEDGMENTS

This work was co-financed from the European Social Fund through Sectoral Operational Programme Human Resources Development 2007-2013, project number POSDRU/89/1.5/S/63258 "Postdoctoral school for zootechnical biodiversity and food biotechnology based on the eco-economy and the bio-economy required by eco-san-genesys".

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PETRI NET BASED MODEL OF SUGAR BEET (BETA VULGARIS) NUTRITION FOR INTEGRATED SUGAR PRODUCTION MANAGEMENT

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SUMMARY

A model using the Petri net formalism is presented. This model allows the evaluation of the chemical composition of the beet plant as a result of the available chemical elements in the environment. The model should provide support in reaching the beet composition that determines high yields in the sugar production through precision fertilisation. It should be used as an integration tool between beet production farm and sugar plant so that the farming conditions can be adapted to the processing needs and the processing conditions to the final farming result. Simulation are performed and compared with data from literature in order to validate the model. The developed model is easy to comprehend and extend and approximates qualitatively well the dynamical composition changes of beet in growth and storage phases.

Key words: Petri Net Modelling, mineral beet nutrition, integrated management

INTRODUCTION

Sugar beet is a technological plant with world economical importance (Francis, 2006) (Elobeid and Beghin, 2006). According to the current management system for scheduling production, price and benefits is made prior to harvest (Ali, 2004). This requires an accurate estimation of the technological quality of sugar beet. To this end, a series of models have been developed (Smith and Struik, 1995) which classify models as the complexity and scope of use. There are simple models for determining the production of beet and the sugar yield, as SUNDIAL (Smith et al., 1995) and complex models that try to describe the metabolic processes occurring in the plant by modifying the composition as SUCROS (Spitters et al., 1989) (Launay and Guérif, (2003), SUBEMOpoll (Vandendriessche, 2000) WIMOVAC (Humphries and Long, 1995) or STICS (Jego et al., 2008) for establishing internal and external environmental factors that can affect growth and development of beet.

Prediction of beet composition depending on the culture conditions offers new research directions to establish the optimal cultivation conditions. For example, (Cameron, 2005) propose a biological model simulation to investigate plant response to solar radiation and nitrogen fertilization; the model can be extended to other interactions with the environment: carbon dioxide and water, other fertilizers. The research presented in this paper is oriented in this direction, because it allows a prediction of sugar beet composition and therefore yield. The model developed in this work proposes a prediction of beet composition according to environmental factors and fertilizers applied, allowing corrective action to improve the technological quality, the adaptation of beet processing and determining the optimal timing of harvest. Petri net approach is used to develop the model.

MATERIALS AND METHODS

The Petri net formalism was used for the beet modelling. This formalism is largely used for the modelling of concurrent processes so is suitable for the modelling of the network of competing chemical reaction (Angeli et al., 2007) and physical processes through which the plant interacts with its environment (Matsuno et al., 2000).

A Petri net is a bipartite directed graph. The nodes can be of two types: places which are represented as circles and transition which are represented as rectangles. Entities called tokens can stay in places or can be moved from one place to the other. The token placement called a marking is the representation of the state of the modelled system. Tokens are moved by firing transitions. Only enabled transitions can fire. A transition is enabled if each of the incoming places has at least a token. If the transition fires, a token is removed from each of its incoming places and one token is placed in each of its outgoing places. This can be extended by associating weights to the binding arcs. The weights represent the number of tokens that are transported when the transition fires. Concurrency is modelled through the sharing of an incoming place by multiple transitions. As multiple transitions can be enabled at the same time the model is intrinsic nondeterministic.

The CPN Tools environment was used for the modelling and simulation. This environment uses a high level extension of Petri nets – Coloured Petri nets. Each token has data associated with it – its colour. This data can be transformed through operations that can be associated to the arcs or transition through which the token passes. The operations are described using a support programming language (Jensen and Kristensen, 2009).

In modelling a network of chemical reaction through Petri nets the natural choice is to associate the places with the pools of each chemical species involved in the process. The tokens are storing the information related to the quantity of the related species so that from the marking of the net at a given time the chemical composition and distribution (the state of the modelled system) can be derived. Each transition represents the chemical or physical processes through which mass is added to or extracted from the pool.

As described in (Dadar, 2013) the resulting Petri net when simulated reproduces the numerical method of solving the ODE system that describes the interacting processes. The original contribution is the use of real number for the fluxes as opposed to the integer number of tokens and the use of timed transitions. This brings the results of the simulation closer to the results of the numerical integration of the ODE system.

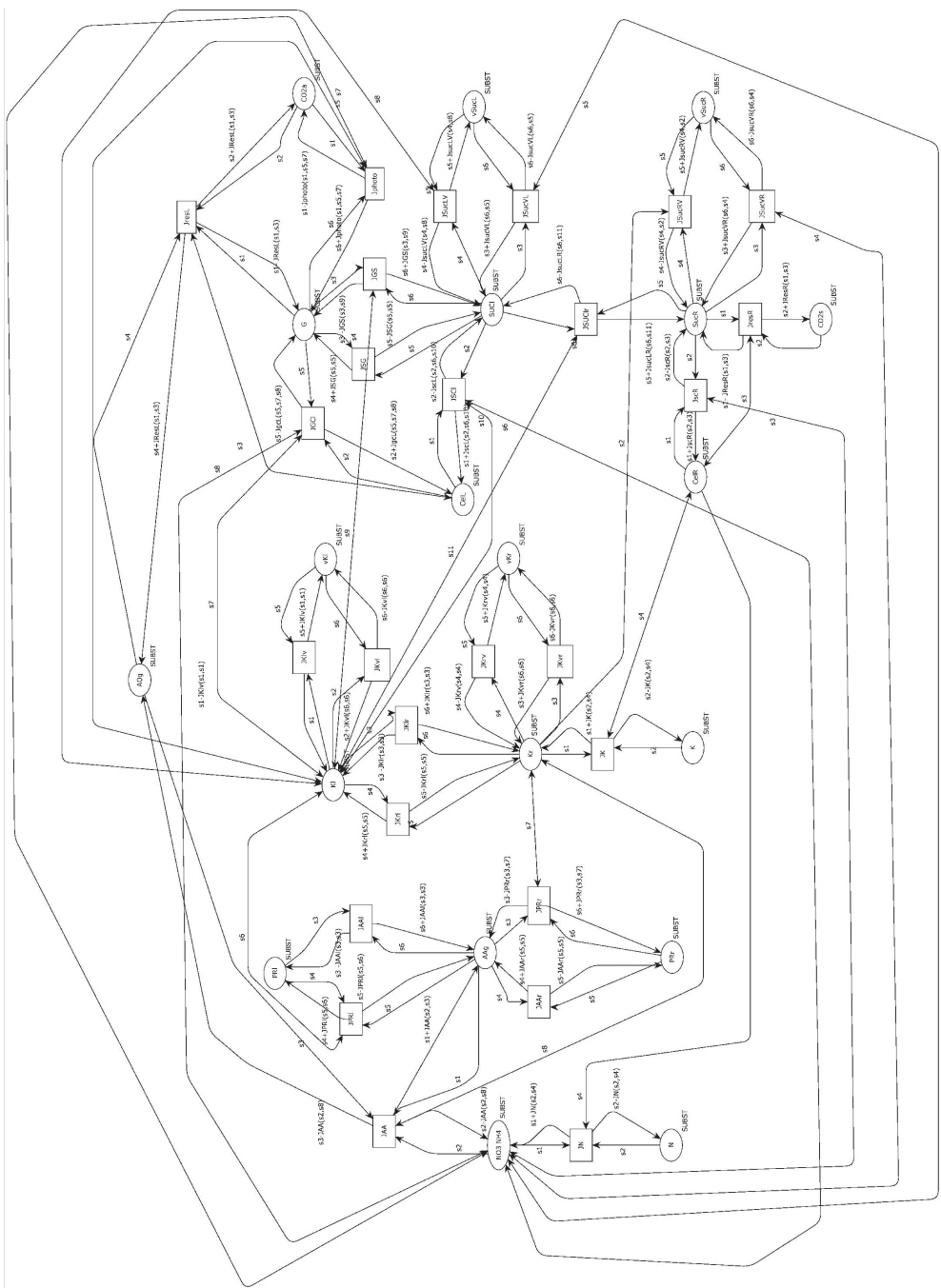


Figure 1 Petri net model of the sugar beet metabolism

The model is limited to one phase - the maturity of beet. The main aspects of this phase, implemented in the model, are:

- the storage of sugar and the associated thickening of the root. The plant tries to equilibrate the growth so that it adds a pair of leaves for each new root ring;
- the increase in potassium demand and the constant demand of nitrogen;
- the increase in storage measures as a result of the nitrogen shortage with root as the main destination for nitrogen, sugar and biomass.

The resulted Petri Net model is presented in Figure 1. For each component of interest separate pools were defined for structural distinct compartments of the plant with transitions modelling the transport processes. This interconnected pools form the pathways for the three elements of interest C, N and K. Two type of connection between the pools were implemented. When pools exchanges masses the arcs binding the corresponding places to the common transition are unidirectional. When pools exchange only information – modelling influences without mass contribution bidirectional arcs are used.

The component distribution between the compartments is regulated by a hormonal control system implemented using the suggestion from literature (Cameron, 2005) (Werker et al., 1998) (Yin and Schapendouk, 2004). The C pathway is represented by glucose (GL), organic acids (AOg), sucrose (SUC) and structural biomass (CEL) pools in root (r), leaf (l) and total (g); the implied processes are photosynthesis in leaf, the leaf biomass synthesis, sucrose synthesis, transport and storage in leaf and root vacuoles, leaf and root respiration and root biomass synthesis.

The N pathway include the mineral nitrogen (NO_3), amino acid (AA) and functional biomass (PR) pools; the processes are the uptake from soil, amino acid synthesis (link to the C pathway), conversion of amino to organic acid, root and leaf functional biomass synthesis. The K pathway include (K) from root and leaf, both “free” and vacuolar (v) and the processes are the uptake from soil and passive and active transport. The K and N in soil pools are given as parameter and can serve as interface with other systems (blocs).

Each process is represented by a transition named with the same symbol as used for the corresponding flux of matter (J). For each such flux functions were written in the support language of CPN tools. The function use Michaelis - Menten kinetics with or without substrate and product inhibition with maximal rates derived from stoichiometrical or physical considerations to calculate the fluxes. The functions are used in the arc inscriptions to update the token values

Also, the processes that are being abstracted like photosynthesis, respiration, water transport and root absorption of nutrients are implemented through functions attached to the responsible structures: leaf protein and root biomass. For the water transport, the osmotic and hydrostatic pressure differences and cumulative plant resistance were used (Amodeo et al., 1999) (Feddes and Raats, 2004) (Hopmans et al., 1997).

RESULTS AND DISCUSSION

System solutions are presenting in order to reflect the changing composition of beet growing in the range of 15 days during the maturity period.

In the nitrogen pool are analysed: proteins PR, inorganic nitrogen NO₃, glutamines and potassium K linked to amino acids AA. The evolution of these components in beet root (index r) and beet leaf (index l) is presented for two potassium concentrations in soil: 24 mg/g (Figure 2a) and 45 mg/g (Figure 2b) and three nitrogen fertilization levels (0.075 mg/g, 0.75 mg/g and 1.25 mg/g nitrogen).

The carbon pool is analysing the sucrose content, cellulose content, organic acids and potassium content bound to this. The evolution of these components in the carbon pool leaf and root is presented in Figures 3a and b.

This approach allows assessments of the evolution of individual components and also the estimation of some quality indicators (such as the amount of dry matter in leaf and root) and the evolution of non-sugars which gives sugar loss in molasses: soluble nitrogen and alkali metals.

Regarding the individual evolutions, continued growth of the protein is found, both in leaf and root. Nitrogen distribution ratio between the two components is favourable for leaves, because leaf foliage grows more than root in the survey period. Increasing the dose of nitrogen increases the plant protein in both parts of plant.

Increasing the dose of potassium determines an especially significant increase in leaf protein. In the literature it is noted that a low level of potassium in the soil reduces leaf protein and a slowdown in plant evolution (Johnston, 2004) (Krauss, 2004) (Kraus and Johnston, 2002).

The amount of glutamine remains almost constant over time and is influenced, however, by the nitrogen dose and not by the level of potassium in soil.

Potassium held by amino acid decreases in time, as confirmed in the literature (Krauss and Johnston, 2002), but depends in high amount on the potassium level in soil.

Regarding the components from the carbon pool, sucrose from root increases continuously and this accumulation is favoured by potassium level; instead, sucrose from leaves remains constant and is not influenced by the potassium levels.

Marc (given by cellulose) from beet root remains almost constant and is not influenced by the level of potassium; in exchange, marc leaf increases over time due to leaf maturation and increases slightly with increasing potassium level.

Organic acids remain almost constant during the same period and are not influenced by the level of nitrogen; on the other hand, the potassium bound to these acids increases with higher potassium levels.

The components evolution resulted from the model is confirmed by the literature (Vanderdriessche and van Ittersum, 1995). Also, non-sugars from sugar beet could be appreciated, in particular the non-sugars which give molasses, namely those bound to amino acids or inorganic acids. Conversely, potassium bound to organic acids is generally generator of natural alkalinity, so it can improve the sugar yield.

The model is in concordance with the qualitative evolution described in literature (Johnston, 2004) (Krauss, 2004) (Kraus and Johnston, 2002), following the same tendencies.

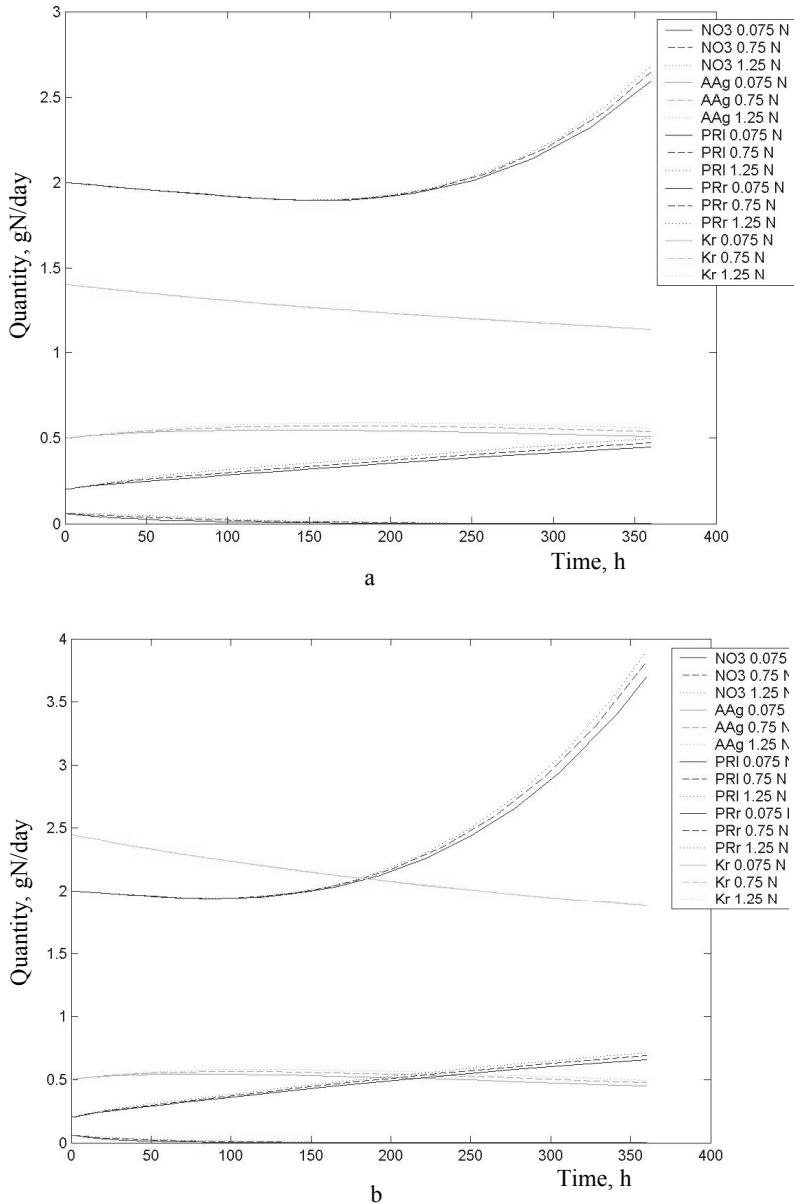


Figure 2 Evolution of proteins (PR), inorganic nitrogen (NO₃), glutamins and potassium (K) linked to amino acids (AA) in beet root (index r) and beet leaf (index l) for two potassium concentrations: 24 mg/g (a) and 45 mg/g (b) and three nitrogen fertilization levels (0.075 mg/g, 0.75 mg/g and 1.25 mg/g nitrogen)

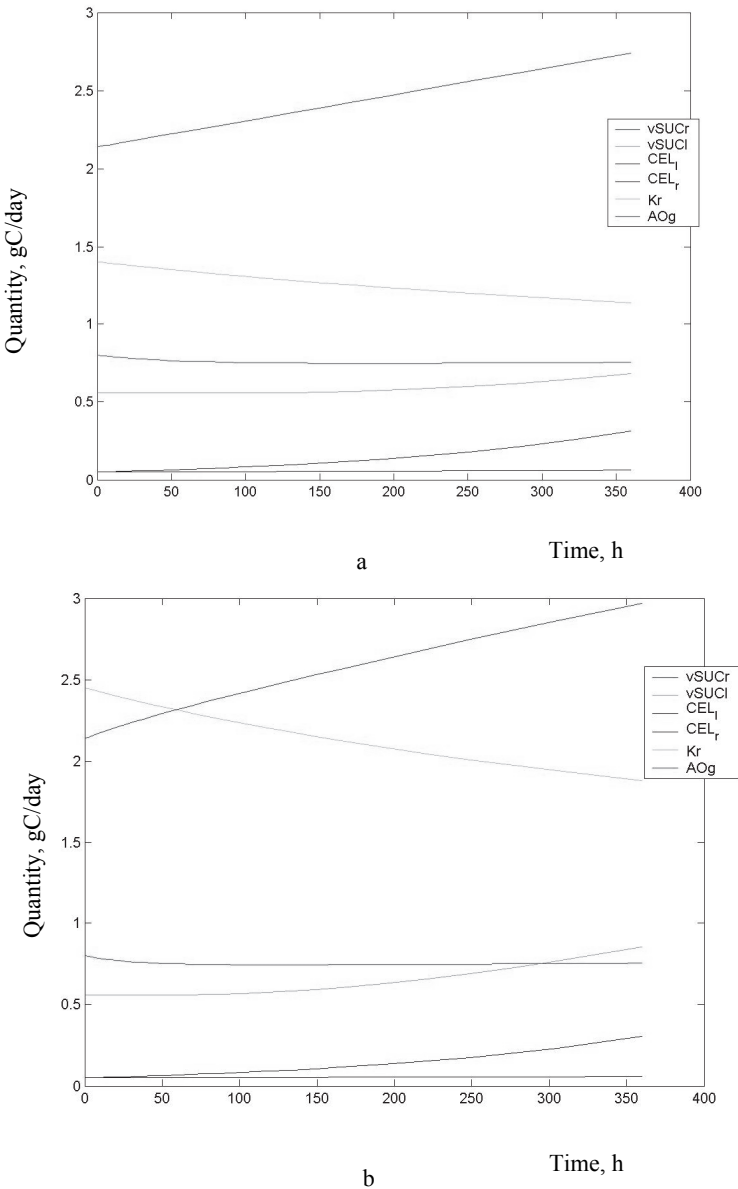


Figure 3 Evolution of sucrose content (SUC), cellulose (CEL), potassium (K) and organic acids (AO) in beet root (index r) and beet leaf (index l) for two potassium concentrations: 24 mg/g (a) and 45 mg/g (b)

CONCLUSIONS

The developed model is easy to comprehend and extend and approximates qualitatively well the dynamical composition changes of beet in growth and storage phases. The model allows predictions of the evolution of beet composition. Sugar content and dry matter can be estimated. The possibility of predicting potassium and amino nitrogen content of the beet allows the choice of an optimal potassium level so that a natural alkalinity reserve favourable to beet processing is reached at the end of the cultivation.

Quantitatively, the model is less sensitive to the nitrogen levels in soil and further fitting of the model is required.

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EVALUATION OF METALS CONCENTRATIONS IN ROMANIAN WINES BY GRAPHITE FURNACE AAS

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SUMMARY

The metals concentrations in wine can be related to factors operating before the grape berry is harvested and to factors affecting it through the processing, sale and consumption. Wine can be viewed as a source of heavy metals needed for nutritional reasons, but it may also expose the consumer to undesirable doses or kinds of heavy metals. Even if not toxic in the short to medium term, the heavy metals may pose a cumulative risk especially when the individual has a high exposure to these metals from other sources.

A large set of analytical techniques have been applied to quantify the trace metal content of wines, in particular attention to sample preparation for good accuracy, as: ion chromatography (IC), stripping potentiometric, inductively coupled plasma mass spectrometry (ICP-MS), inductively coupled plasma atomic emission spectrometry (ICP-AES), flame atomic absorption spectrometry, and graphite furnace atomic absorption spectrometry (GFAAS). Modern GFAAS systems generally meet the aforementioned requirements and also offer the possibility of multi-element analysis. Thus they have been applied to the simultaneous determination of trace elements in agriculture for complex material systems as: foodstuff, seawater, mineral water, blood, urine, Al-alloy, aerosol, honey, and wine samples.

The object of research was to investigate the degree of Romanian wines contamination with nickel, copper and zinc. Factors that may contribute to copper endogenous and exogenous presence are cupric treatments of the vineyard, rains before harvest, the amount of SO₂ used during wine production, the materials used in various technological operations, levels of oxidation-reduction during these operations. Nickel can be present in wines owing to the use of Ni-containing stainless-steel containers for wine fermentation and storage in modern cellar technology.

Twenty wine samples were tested using graphite furnace atomic absorption spectrometry, after a specific microwave mineralization procedure, which implies the use of Microwave Digestion Systems Mars 5 equipped with microwave acid digestion bombs made from Teflon and having 100 ml capacity.

Ni concentration varies between 41.442 and 126.568 $\mu\text{g/l}$, Cu concentration varies between 0.001 $\mu\text{g/l}$ and 1897.234 $\mu\text{g/L}$ and Zn varies between 297.999 $\mu\text{g/l}$ and 1562.009 $\mu\text{g/l}$.

Different metals occur in wines at the mg/l and/ or $\mu\text{g/l}$ level not directly influencing the taste of the end product. Nevertheless, their content should be determined because excess is undesirable due to potential toxicity and risks to human health, consequently imposing the maximal allowed values and/or prohibited limits. The content of the investigated metals was considerably lower than the maximum concentrations allowed according to the OIV.

Key words: *Romanian wine, heavy metals, graphite furnace atomic absorption spectrometry (GFAAS)*

INTRODUCTION

Heavy metals toxicity represent a less common medical situation, but still clinically significant. If not recognized and treated properly, it can cause significant morbidity and mortality. The Periodic Table of the Elements contains 105 elements, of which 80 are considered to be metals, and for less than 30 of these toxic effects have been described in humans. Some heavy metals are essential in various biochemical processes (e.g. Zn, Cu, Cr, Fe, Mn - necessary for organism in small amounts, becoming toxic in large quantities).

Literature mentions that elements such as Cu, Fe, Mn, in large quantities may affect the stability of the wine, thus their sensory characteristics [4], [5]. Another category of metals introduced in wine in anted quantities leading to the so-called unwanted scrap metal, (Fe, Cu, Zn, Cr, Pb, As) [10], [2]. Iron serves to catalyse the formation of phenolic compounds and manganese favours the formation of acetaldehyde [6], [3]. Copper, iron, manganese amino acids form stable components with amino acids and polyphenols, copper giving the wine unpleasant taste in the presence of high concentrations of tannin and increased pH [1], [11], [12]. Nickel often occurs at low concentrations in the wine due to the improperly used equipment [8], [9].

European standards severely limit the concentrations of heavy metals, knowing the fact that currently there are effective systems to reduce them. In the wines, these metals usually came from vines, fruit, soil, air, and water, sometimes from erroneous handling or poor hygiene [7], [13].

The aim of this study was the determination of Ni, Cu and Zn concentrations from 20 samples wine from various Romanian vineyards.

METHODS

For this study there were selected twenty samples of white wine, Sauvignon Blanc and Feteasca Regala harvested in 2013 from the following vineyards: Aiud, Cotnari, Craiova

Hills, Dragasani, Husi, Murfatlar, Recas, Samburesti, Severin, Stefanesti. For this wine samples there were determined the concentration of three transitional metals (Ni, Cu, Zn) using atomic absorption spectroscopy with graphite furnace (GFAAS experiments were performed on an Analytic Jena ZEENIT 700), after a specific microwave mineralization procedure, which implies the use of Microwave Digestion Systems Mars 5 equipped with microwave acid digestion bombs made from Teflon and having 100 ml capacity. For quantitative determinations, it was obtained a calibration curve for each element.

RESULTS AND DISCUSSION

Nickel is found in very small amounts in grapes, but can get in wine through installations and equipment. In the analyses samples, Ni concentration have micrograms order values, the minimum value determined by GFAAS being 41.442 $\mu\text{g/l}$ for the Sauvignon Blanc wine originated from Aiud, and the maximum value reaching 126.568 $\mu\text{g/L}$ in the Feteasca Regala wine from Dragasani (figure 1).

Even though the wines came from the same winery, there can be observed different values of nickel depending on the wine type: for Sauvignon Blanc wine from Aiud the Ni concentration was 41.442 $\mu\text{g/l}$, but in Feteasca Regala wine the concentration was about 50% higher, reaching values of 65.223 $\mu\text{g/l}$ nickel. For the wines from Dragasani, Husi, Stefanesti and Samburesti vineyards, significant differences have been reported, nickel values determined being even 100% higher between varieties. In Husi Vineyard, Sauvignon Blanc wine has a nickel concentration 49.657 $\mu\text{g/l}$, while in the same vineyard Feteasca Regala accumulates 103.444 $\mu\text{g/L}$. An opposite situation is found in vineyard Samburesti, Sauvignon Blanc wine having a nickel concentration of 111.011 $\mu\text{g/l}$, compared with Feteasca Regala wine that accumulates only half, 48.999 $\mu\text{g/l}$.

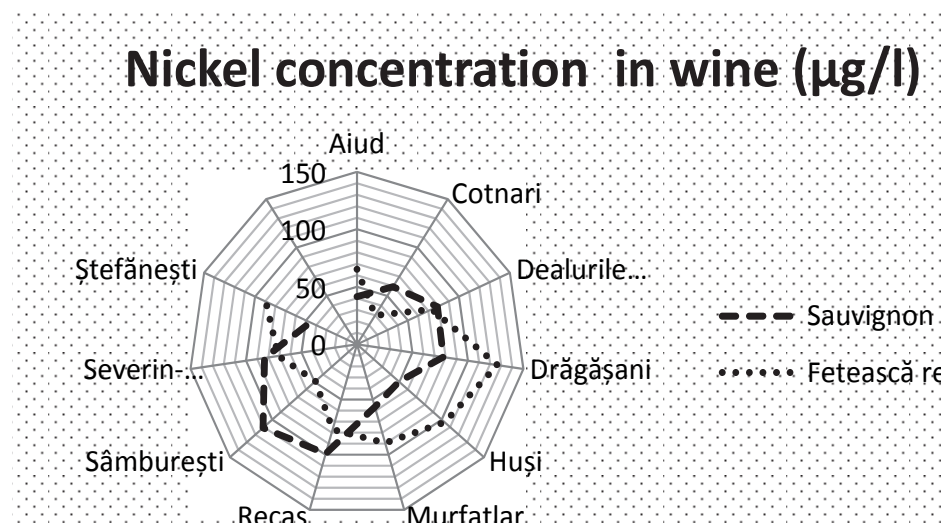


Figure 1 Nickel variations in wines depending on vineyard and wine sort

Copper is one of the metals that can be introduced in wine by treating wine or grape vines with copper sulphate to eliminate the defects of taste or smell, the permissible values being governed by Resolution no. 769 of 28 July 2010, for the approval of the Methodological Norms for applying 244/2002 Wine and wine Law. These values must not exceed 1 g of copper sulfate / hl.

Figure 2 shows that in the Aiud vineyard, the copper values determined for the Feteasca Regala wine are almost zero, (0.001 $\mu\text{g/l}$), while in the Recas vineyard these values reach a maximum in Sauvignon blanc wine (1897.234 $\mu\text{g/l}$).

The values obtained for the Sauvignon blanc wines from the other vineyard are: Craiova Hills 25.998 $\mu\text{g/l}$, Stănești 28.144 $\mu\text{g/l}$, Cotnari 451.992 $\mu\text{g/l}$ and Dragasani 301.337 $\mu\text{g/l}$. For the Feteasca Regala wine the copper concentrations are: Severin-Corcova 77.024 $\mu\text{g/l}$, Samburești 38.992 $\mu\text{g/l}$, Cotnari 234.109 $\mu\text{g/l}$ and Dragasani 299.314 $\mu\text{g/l}$.

Zinc is one of the trace elements present in wines, having reduced beneficial effects on the human body.

Zn concentration is between 297.999 $\mu\text{g/l}$ for Sauvignon Blanc wine originated from Aiud and 1562.009 $\mu\text{g/L}$ for the same sort of wine coming from Murfatlar.

Similar values present wines from Cotnari (467.012 $\mu\text{g/l}$) - for Sauvignon Blanc wine, and 512.334 $\mu\text{g/l}$ for Feteasca Regala; Craiova Hills 345.123 $\mu\text{g/l}$ for Sauvignon Blanc and 417.72 $\mu\text{g/l}$ for Feteasca Regala; Recas – 430.965 $\mu\text{g/l}$ for Sauvignon Blanc and 567.981 $\mu\text{g/l}$ for Feteasca Regala; Stănești – 301.789 $\mu\text{g/l}$ for Sauvignon Blanc and 419.219 $\mu\text{g/L}$ for Feteasca Regala.

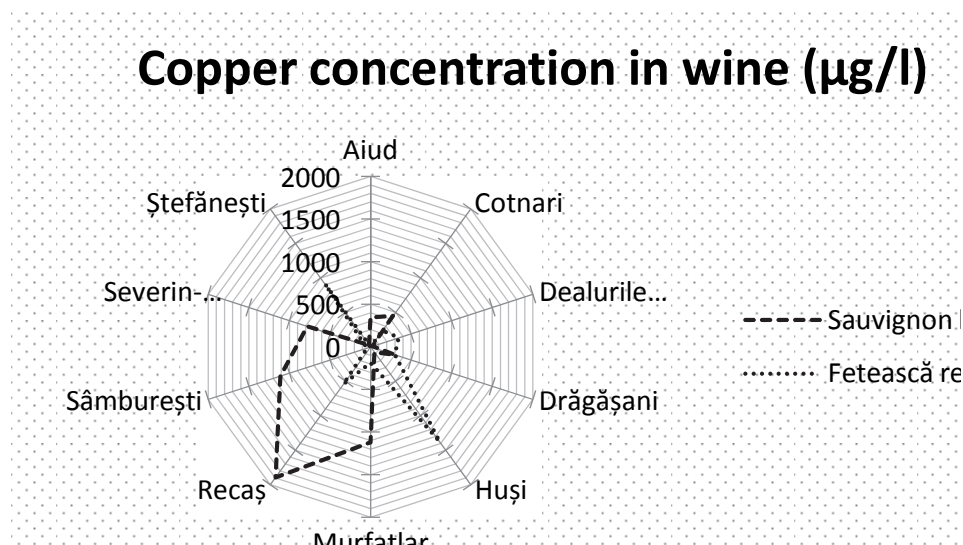


Figure 2 Copper variations in wines depending on vineyard and wine sort

For Samburești vineyard, Zn concentration in Sauvignon Blanc wine reaches 1512.76 $\mu\text{g/l}$ and in Feteasca Regala wine it reaches 1245.012 $\mu\text{g/l}$.

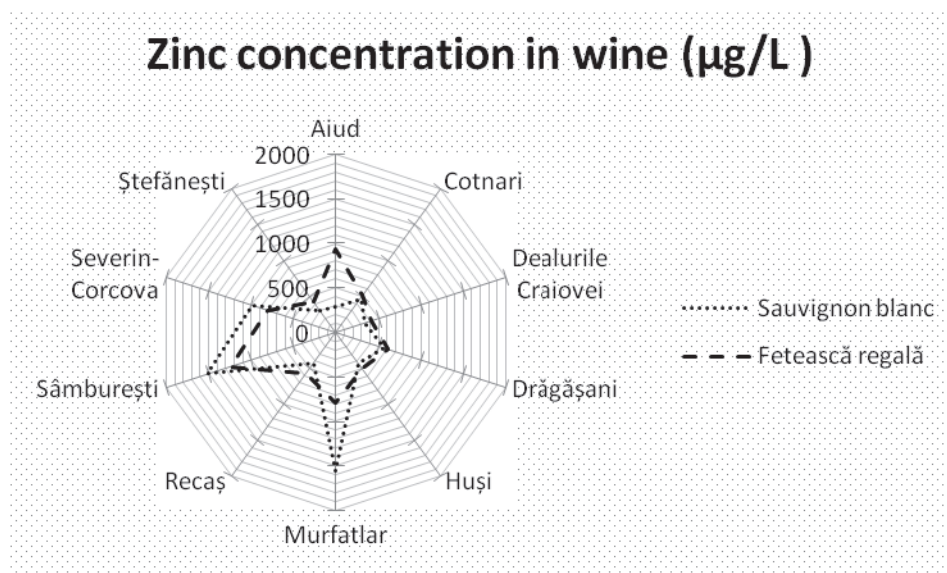


Figure 3 Zinc concentrations in wines depending on vineyard and wine sort

CONCLUSIONS

The method for determination of transitional metals using GFAAS leads to very precise results.

The nickel concentration determined for the studied samples does not exceed the maximum values allowed by the regulations even there were noticed significant fluctuations both between the vineyards and also the studied wines varieties.

Copper and Zinc are essential micronutrients for the humans, and the concentrations found in the wines can be beneficial, without exceeding the normal limits.

There was no evidence to lead to the hypothesis of soil contamination in any of the vineyards even if values fall within generous limits.

ACKNOWLEDGMENTS

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/159/1.5/S/133675.

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DETERMINATION OF THE QUALITATIVE INDICES OF AN UV-C INSTALLATION FOR MICROBIAL REDUCTION ON THE EXTERIOR OF HORTICULTURAL PRODUCTS

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SUMMARY

Fruits and vegetables consumed fresh, can be carriers of some optional pathogenic microorganisms: bacteria, yeasts, molds. These microorganisms can cause either loss of horticultural products in the storage process, due to the post harvest decay process or food-borne diseases with direct effects on consumer human health. Of particular importance in order to obtain a bigger acceptable duration for the storage of the horticultural products consumed fresh, is to provide a low microbiological load at the beginning of the refrigeration process. In the paper are presented experimental researches on the possibility of using non-ionizing ultraviolet radiation UV-C within the conditioning technologies of horticultural products, by investigating the capability of an experimental model of installation for the decontamination of external surfaces of horticultural products, to apply the minimum dosage recommended for the destruction of the most representative pathogens.

Key words: post harvest treatment, microbial count, UV-C radiation, fruits and vegetable, shelf-life

INTRODUCTION

Fruits and vegetables are one of the indispensable components of rational human consumption. Consumed fresh, can be carriers of some optional pathogenic microorganisms: bacteria, yeasts, molds. These microorganisms can cause either loss of horticultural

products in the storage process, due to the post harvest decay process or food-borne diseases with direct effects on consumer human health.

Of particular importance in order to obtain a bigger acceptable duration for the storage of the horticultural products consumed in fresh-state, is to provide a low microbiological load at the beginning of the refrigeration process. This requires to minimize the possibility of microbiological contamination of the products in all stages prior to the refrigeration stage itself.

Losses of horticultural products, due to the post-harvest decay process, are at the level of 10-50% depending on the degree of development of the area and the facilities for temporary storage. In order to limit these losses, there have been used synthetic fungicide substances. Residues of these substances, which remain on the surface of horticultural products, after treatment, are considered a potential threat to consumer health and especially children (Kasim et al., 2007).

Many outbreaks of gastroenteritis have been associated with the consumption of contaminated horticultural products (Franz and van Bruggen, 2008). In order to reduce microbial contamination, there have been used widely, chlorine-based cleaning systems, being a significant interest in developing methods for safe and efficient decontamination of horticultural products (Hinojosa et al., 2013). Several alternative disinfectants (including hydrogen peroxide, organic acids and ozone) have been tested to reduce bacterial populations (Allende et al., 2006; Silveira et al., 2008; López- Gálvez et al., 2009).

Conventional thermal methods of food sterilization are unsuitable for fruits and vegetable destined for fresh consumption because of the heat which cause inevitable changes of color, smell, flavor and a loss of nutritional value (Perni et al., 2008).

Conventional antimicrobial treatments for fresh produce rely on chemical compounds and physical contact to inactivate and remove bacterial contamination. Recent research has identified a number of energy-based alternative technologies to improve the safety of fresh and fresh-cut fruits and vegetables: ultraviolet radiation, electron-beam irradiation, technology with pulsed visible light and technology with cold plasma.

Within the methods earlier mentioned, a special potential has the use of non-ionizing ultraviolet radiation UV-C. The wavelength range that varies between 200 and 280 nm, which is considered lethal to most types of microorganisms, affects the DNA replication of these microorganisms (Bintsis et al., 2000; Char et al., 2010).

Non-Ionizing UV radiation can cause breaks of molecular chemical bonds and can induce photochemical reactions. All nutritional and toxicological undertaken studies showed the absence of any adverse effects of ions, excited atoms and molecules generated during irradiation. The DNA damage by irradiation to undesirable microorganisms, leads to their inactivation. The amount of energy can be controlled to achieve desired effects in terms of conservation, while maintaining quality, safety and nutritional properties of the food. The biological effects of UV radiation depends on the wavelength and the exposure time.

In the spectrum of electromagnetic radiation, the ultraviolet radiation are between X-rays and visible radiation with wavelengths between 40 and 400 nm, and the energy varies from 3 to 30 eV. UV spectrum comprises five distinct regions: extreme-UV (40...190 nm), far-

UV (190...220 nm), UV-C (220...290 nm), UV-B (290...320 nm) and UV-A (320...400 nm) (Baran et al., 2009).

The UV radiations from the extreme-UV, far-UV and UV-C are almost nonexistent in nature, because they are completely absorbed in the atmosphere. Artificial sources of UV light are produced by the lamps of low pressure or high / medium pressure. Low pressure lamps produce, essentially, monochromatic light at a wavelength of 253.7 nm, very close to the peak of germicidal efficiency, respectively 264 nm. These lamps are available with ozone producing and non-producing ozone. Medium pressure lamps produce a polychromatic light on a broader spectrum.

Non-ionizing ultraviolet radiation UV-C is used as an alternative to chemical sterilization and microbial reduction in food products and has been approved for use as a disinfectant for surface treatment of food (US-FDA, 2002). As a postharvest treatment on fresh produce, UV-C irradiation has been proven beneficial to reduce respiration rates, control rot development, and delay senescence and ripening in different whole or fresh-cut fruits and vegetables, such as apples, citrus, peaches, watermelon, grape berries, tomatoes, lettuce, baby spinach and mushrooms (de Capdeville et al., 2002; Lamikanra et al., 2005; Allende et al., 2008; Artés-Hernández et al., 2010; Escalona et al., 2010; Jiang et al., 2010; Fava et al., 2011; Manzocco et al., 2011). Furthermore, UV-C has also been shown to elicit a range of biochemical responses in fresh produce ranging from induction of antifungal enzymes to formation of phytoalexin compounds (Guan et al., 2012), elements which have been positively correlated with resistance against several pathogens and reduction of physiological disorders occurring during cold storage of fruits and vegetables (Rivera-Pastrana et al., 2007). Another advantage of applying UV-C is the capability to improve nutraceutical properties, due to an increase of bioactive compounds with antioxidant capacity.

The extension of the shelf-life of food is nowadays a challenge for the research with application in food industry. Thus, the researches undertaken to test the UV-C decontamination method in order to extend the shelf-life of fresh or minimally processed horticultural products, focuses on the following approaches:

- performing experimental researches on the possibility of using non-ionizing ultraviolet radiation UV-C within the conditioning technologies of horticultural products;
- investigating the capability of an experimental model of installation for the decontamination of external surfaces of horticultural products, to apply the minimum dosage recommended for the destruction of the most representative pathogens.

METHODS

According to existing studies in the field, among the most common microorganisms that can contaminate horticultural products, with adversely affect on storage or human health, include those shown in Table 1. For the destruction of these potentially pathogenic microorganisms, it is recommended to apply certain doses of UV-C radiation.

Given the above issues, the experimental researches on the possibility of using non-ionizing ultraviolet radiation UV-C within the conditioning technologies of horticultural

products, have focused on investigating the capability of applying the minimum dosage recommended for the most representative pathogens. In this respect, it was experimented a new technical equipment (fig. 1) - Installation for the decontamination of external surfaces of horticultural products, IDPH, designed and manufactured within INMA Bucharest.

Table 1 Potentially pathogenic microorganisms and recommended UV-C radiation doses (www.midasexpert.ro)

Microorganism	UV-C radiation dose [mWs/cm^2] necessary for the destruction of	
BACTERIA	90 %	99 %
Bacillus anthracis	4.52	8.70
Clostridium tetani	13.00	22.00
Escherichia coli	3.00	6.60
Mycobacterium tuberculosis	6.20	10.00
Salmonella enteritidis	4.00	7.60
Shigella dysenteriae	2.20	4.20
Staphylococcus aureus	2.60	6.60
MOLDS		
Aspergillus flavus	60.00	99.00
Penicillium expansum	13.00	22.00
Rhizopus nigricans	111.00	220.00
YEASTS		
Saccharomyces spores	8.00	17.60

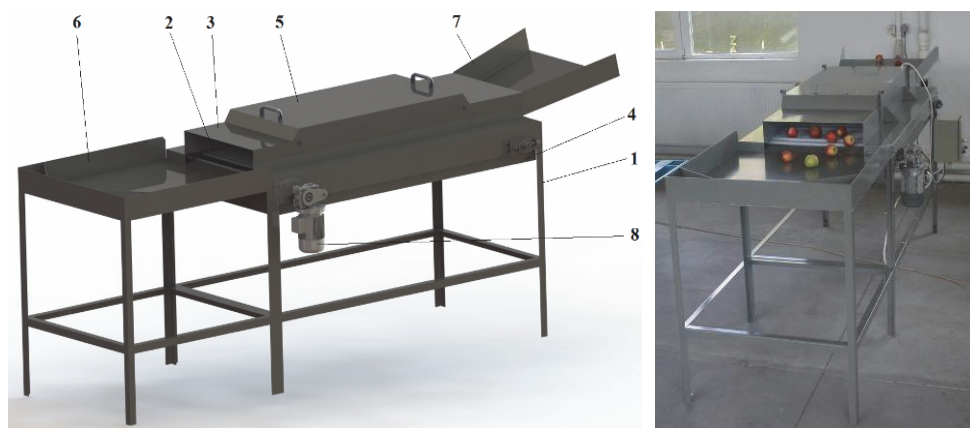


Fig. 1 Installation for the decontamination of external surfaces of horticultural products, IDPH, (3D model – left side; physical model – right side)

The installation used for the decontamination of external surfaces of horticultural products, as preliminary stage for the temporary storage phase itself, is composed of the following main assemblies: frame - pos. 1, transport system - pos. 2, upper casing - pos. 3, lower casing - pos. 4, UV-C module - pos. 5, collection table - pos. 6, supply cuvette - pos. 7 and gearmotor - pos. 8. The main characteristic of the transport system is that it performs not only the transportation of the product along the installation but also the rotation of it around an axis perpendicular to the direction of advance. This characteristic assures a homogenous distribution of the UV-C radiation upon the exterior surfaces of the products.

The main technical characteristics of the decontamination installation are:

- Dimensions (LxWxH): 3420x1215x1340 mm;
- Length of the transport system: 1500 mm;
- UV Generator type: discharge lamps at low pressure mercury vapor;
- The wavelength of the emitted radiation: 253.7 nm (UV-C);
- Power of the UV-C lamps: 55 W / pcs.;
- Number of UV-C lamps: 5 pcs.

The experimentation was aimed to determine the qualitative working indices of the decontamination installation. For this purpose, there were taken into account the following parameters:

- The minimum and maximum rotational speed of the driving system of the conveyor - there were determined by varying the frequency of the supply current of the gearmotor, through the frequency converter currently existing within the automation installation;
- The minimum and maximum transport time - there were determined by measuring the time needed for a product subjected to decontamination, to pass a length of the transport system, in terms of maximum and minimum rotational speed of the driving system.

In order to determine the intensity of non-ionizing ultraviolet radiation UV-C, there were performed measurements using a set of tools, sglux brand, Germany, comprising of the following elements: an intensity sensor for ultraviolet radiation, calibrated for the UV-C spectrum (UV Sensor "UV-Water-D"), a communication interface between the sensor and the laptop ("DIGIBOX" - CAN-to-USB converter) and a data acquisition software for the radiation intensity and air temperature, based on LabView programming environment ("DigiLog").

There were performed determinations at different distances from the source of radiation (50 mm, 75 mm, 100 mm and 125 mm) in the space between two adjacent UV-C lamps. The aim was to highlight the influence of the distance on the intensity of emitted UV-C radiation. Also, there were calculated the UV-C radiation doses, according to the measured radiation intensity and its duration of application, using the equation:

$$D = I \cdot t \text{ [mWs / cm}^2\text{]} \quad (1)$$

The durations of application for the UV-C radiation were considered to be the minimum and maximum time that a product needs to pass through the transport system of the installation.

RESULTS AND DISCUSSION

After carrying out experimental researches on the installation for the decontamination of external surfaces of horticultural products, there were achieved a series of results regarding the qualitative indices of the decontamination installation. These results are presented in Table 2.

Table 2 Qualitative indices of the decontamination installation

No crt.	Parameter	Measure unit	Parameter values determined from tests			
1.	The distances from the source of radiation	mm	125	100	75	50
2.	The intensity of UV-C radiation	mW/cm ²	2.64	3.14	3.76	5.89
3.	The minimum UV-C radiation dose, according to the minimum transport time	mWs/cm ²	7.74	9.20	11.02	17.26
4.	The maximum UV-C radiation dose, according to the maximum transport time	mWs/cm ²	118.80	141.30	169.20	265.05

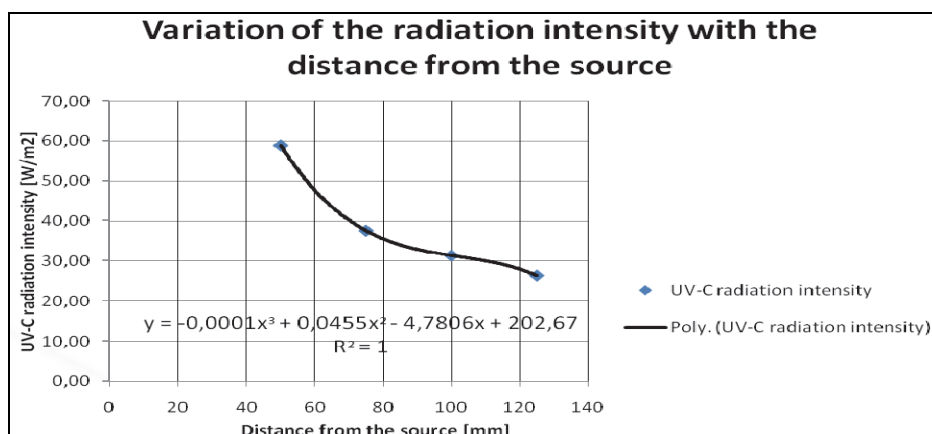


Fig. 2 Variation of the radiation intensity with the distance from the source

The radiation intensity values from Table 2 represent the average of the values obtained during the sampling interval. The minimum and maximum doses at various distances from

the source of UV-C radiation were calculated based on relation (1), considering the minimum and maximum time that a product needs to pass through a length of the transport system.

Figure 2 shows the variation of UV-C radiation intensity with the distance from the source of radiation.

Linear regression performed using Excel, allowed the identification of a third degree polynomial function, which estimates the variation of the radiation intensity depending on the distance from the source, with a maximum coefficient of determination.

Figure 3 shows the variation of minimum and maximum dose of UV-C radiation with the distance from the source of radiation.

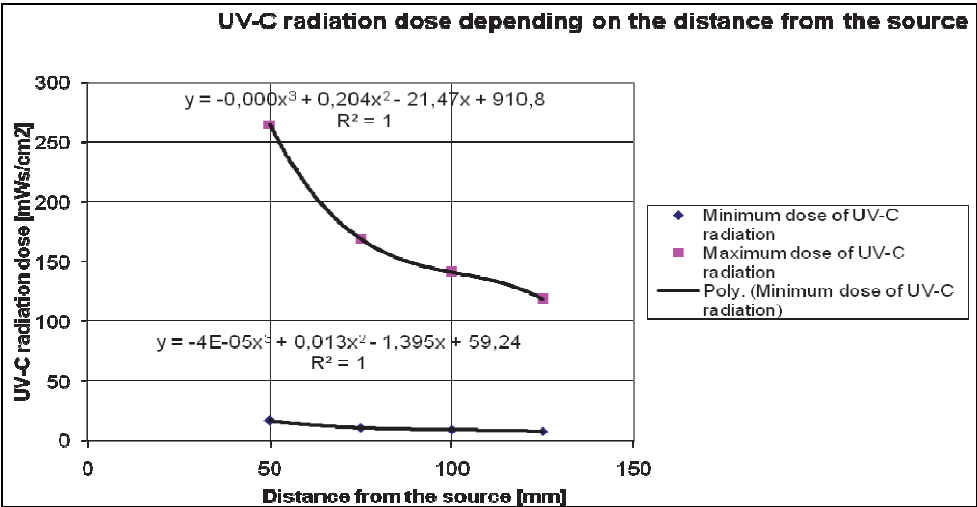


Fig. 3 Variation of minimum and maximum dose of UV-C radiation with the distance from the source



Fig. 4 Aspects during the determination of the minimum and maximum transport time

Also, using linear regression was identified a third degree polynomial function, which estimates the variation of UV-C radiation dose depending on the distance from the source, with a maximum coefficient of determination.

Some aspects during the determination of the qualitative indices of the decontamination installation, are shown in Figures 4 and 5.

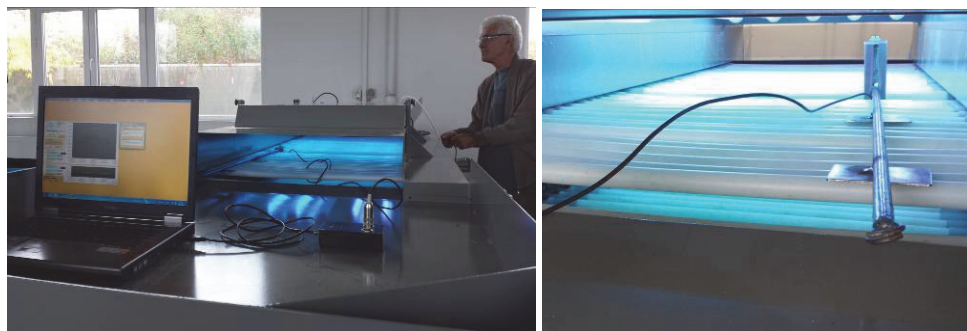


Fig. 5 The determination of the UV-C radiation intensity

CONCLUSIONS

Following the analysis of the obtained experimental data and the data contained in Table 1, regarding the UV-C radiation doses recommended for the destruction of the most common potentially pathogenic microorganisms existing on the exterior surface of the horticultural products, it is found that the experimented decontamination installation has the capability to achieve quality indices superior to the recommendations in Table 1. However, although the installation is able to provide radiation doses higher than those shown in Table 1, the product subjected to decontamination receives only half the dose, relative to its entire surface. This statement was set forth taking into account the simplifying assumption that, at a certain moment in time, only the upper half of the product will be exposed to UV-C radiation, the other half being shadowed. Considering this hypothesis, the installation it still achieves a destruction rate of 90% of the most resistant pathogens presented in table 1, even in a single pass, adjusted at 50 mm distance from the radiation source, without having to repeat the exposure to UV-C radiation. For a destruction rate of 99 %, the installation is able to provide the necessary radiation doses for almost all the pathogens in the table 1, except for *Rhizopus nigricans* which needs a higher dose. The next phase of the research will be directed towards the measurement of the microbial count existing on the exterior surfaces of horticultural products.

Given the need to use post harvest treatment methods that enable improvement of the bacteriostatic effect, partly ensured by refrigeration and avoid contamination with toxic residues from the decontamination with chemicals, the use of UV-C ultraviolet non ionizing radiation may be a viable solution. Nutritional and toxicological studies conducted worldwide have shown the absence of any adverse effects of ions, excited atoms and molecules generated during irradiation.

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AGRICULTURAL RESIDUES FOR ANAEROBIC DIGESTION: TECHNOLOGIES TO OPEN UP NEW RESOURCES

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SUMMARY

The utilization of agricultural residues as a substrate for bioenergy production could increase overall renewable energy production, significantly contributing to European Union (EU) policy goals. Unlike traditional energy crops, agricultural residues do not compete with food or feed production and represent a largely unused resource. Agricultural residues are primarily comprised of lignocellulosic material that is difficult to digest in anaerobic digestion processes. Various pretreatments (an array of physical, chemical, and biological methods) can help increase digestion efficiency and biogas production. Steam explosion has proven to be an effective pretreatment method, significantly changing biomass morphology, decreasing hemicellulose content, and increasing methane yields. Life-cycle assessments of steam explosion of select agricultural residues have indicated that this pretreatment can decrease the environmental impacts of biogas production. If used on a broad yet sustainable scale, 117 Mt DM per year of main crop residues could be available in the EU.

Key words: agricultural residues, pretreatment, steam explosion, anaerobic digestion

INTRODUCTION

Currently, fossil resources provide most of the world's energy. Renewable resources still contribute only a very small share (Soetaert & Vandamme, 2009). Moreover, world energy demand is increasing rapidly, mainly to satisfy demand in large developing nations such as China and India. Current energy consumption is fraught with negative externalities

including emissions, environmental problems, deforestation, collapsing ecosystems and undesired climate effects. In addition, society's heavy dependence on petroleum, which is mainly produced in politically unstable countries and regions, has serious geopolitical implications (Soetaert & Vandamme, 2009). Growing concerns about this situation have led to the search for renewable alternatives (Midilli et al., 2006).

Member states of the European Union have agreed to reduce greenhouse gas emissions by implementing a renewable energy directive (European Union, 2009), which states that by 2020, 20 % of the EU's energy must come from renewable sources and that 10 % of renewable energy must be used in the transport sector. However, producing biofuels from biomass can compete directly with food and feed production. On October 17th 2012, the European Commission amended Directive 2009/28/EC, limiting the use of food-based biofuels and promoting advanced biofuels that are produced from feedstock, which does not compete directly with food and feed crops (European Commission, 2012).

Amongst the various renewable energy alternatives, anaerobic digestion (AD) for biogas production is an economical and eco-friendly option that allows the utilization of crops residues and organic wastes, helping to fulfill the objectives set by the European Union. Biogas consists mainly of methane (45 - 75 %) and carbon dioxide (25 - 55 %) (Deublein & Steinhauser, 2008) and offers many advantages including a wide variety of suitable biomass sources, low pollutant emissions, efficient transformation into electrical and thermal energy via a combined heat and power (CHP) engine and the usability of fermentation residues as a fertilizer. Of the numerous biomass candidates for biogas production, agricultural residues are promising contenders. Crop residues mainly consist of three polymer groups: cellulose, hemicellulose and lignin, constituting the so-called lignocellulosic complex. Lignocellulose is the primary structural component of woody and non-woody plant cell walls and constitutes approximately 90 % of the dry weight of most biomass (Yat et al., 2008). Utilizing crop residues for biogas production is challenging, as the lignocellulosic complex creates a protective barrier around otherwise digestible material. The barrier hinders microbial access to cellulose and hemicellulose, which is necessary for conversion to biogas. More specifically, access is hindered by limiting the accessible surface area, by the covalent bonds between lignin and hemicellulose, as well as by cellulose crystallinity (Mosier et al., 2005).

The utilization of crop residues also has other drawbacks due to their physical properties and composition. Crop residues have low bulk density, which has an impact on transport, processing and storage costs in comparison to, for example, maize silage. The moisture content varies significantly and can be either too high for ensiling or too low for storage without further drying. Additionally, contamination with foreign particles (e.g. dust and stones) can impact digestion processes or the life span of processing equipment (Kaltschmitt et al., 2009).

Hydrolyzing the polysaccharides cellulose and hemicellulose into fermentable sugars is essential to the efficient and economical production of biofuels. As such, the application of a pretreatment to alter the structure of lignocellulosic biomass is required (Brekke, 2005; Mosier et al., 2005). Pretreatment ensures that microbial enzymes and acids have access to cellulose and hemicellulose, improving the conversion of polymer to monomer sugars.

PRETREATMENT TECHNOLOGIES FOR LIGNOCELLULOSIC BIOMASS IN ANAEROBIC DIGESTION

Numerous researchers have tested a large variety of pretreatments. These methods can be roughly classified as physical, chemical, biological or as a combination of all three (see Fig. 1). The main goals of the pretreatment step are to improve degradability of biomass, to improve sugar formation (or the ability to subsequently form sugars by hydrolysis), avoid the formation of inhibitory compounds, avoid carbohydrate loss, and increase biomass porosity. Moreover, pretreatments must be economically effective (Kumar et al., 2009).

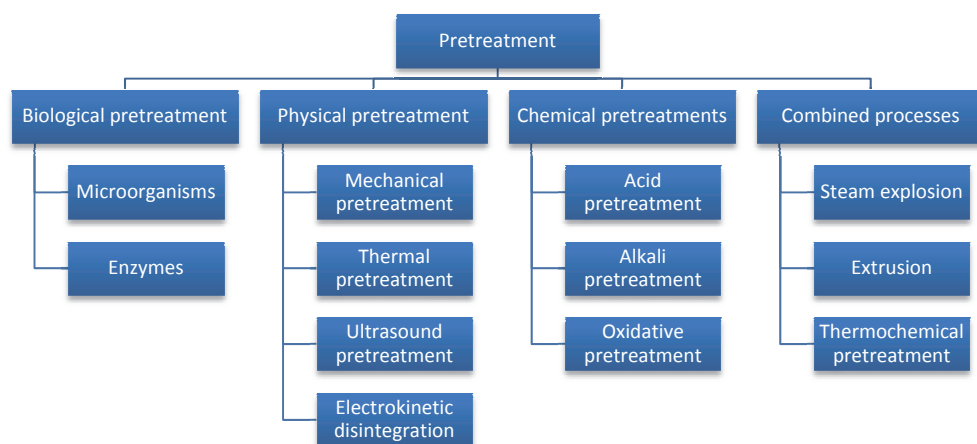


Fig. 1 Overview of pretreatment technologies for lignocellulosic biomass

In biological pretreatments, microorganisms and fungi, such as white, brown, and soft rot-fungi, are employed to degrade the lignocellulosic complex. Biological pretreatments can also be used for the removal of antimicrobial substances. This process has low energy requirements and mild environmental conditions. However, it requires long residence times (Harmsen et al., 2010).

Physical pretreatment can increase the accessible surface area and size of pores, and decrease the crystallinity and degree of cellulose polymerization. The comminution processes include chipping, grinding and milling. Size reduction increases the accessible surface area as well as decreases cellulose crystallinity, improving the digestibility and the conversion of saccharides during hydrolysis (Kratky & Jirout, 2011). Although comminution processes require little initial investment, they require large quantities of energy. Pyrolysis has also been used for the pretreatment of lignocellulosic materials. Solid biomass rapidly decomposes to gaseous and liquid products as well as residual charcoal when it is treated at temperatures greater than 300 °C (Kumar et al., 2009). Irradiation strategies such as gamma ray, microwave and electron beam pretreatments are another option, although the prospects for a commercial-scale operation are minimal.

Chemical pretreatments have the primary goal of improving the biodegradability of cellulose by removing lignin and/or hemicellulose through chemical reactions. This task is

carried out using different chemicals/techniques (Kumar et al., 2009; Shimada et al., 2008; Taherzadeh & Karimi, 2008). Acid hydrolysis pretreatment can result in the improvement of enzymatic hydrolysis of lignocellulosic biomass, releasing fermentable sugars. Alkaline pretreatment removes lignin from the biomass, thus improving the reactivity of the remaining polysaccharides. Organosolv processes mix organic solvents with the lignocellulosic material and heat the mixture in order to dissolve the lignin and part of the hemicellulose. Oxidative delignification can also be achieved by treatment with an oxidizing agent such as hydrogen peroxide, ozone, oxygen or air.

Combined pretreatment technologies, such as physicochemical pretreatment, consist of a combination of physical and chemical processes, either simultaneously or in two steps. Steam explosion pretreatment involves heating biomass to high temperatures, followed by a mechanical disruption of the biomass fibers by a rapid pressure drop. The process causes hemicellulose degradation and lignin transformation (Kumar et al., 2009). In comparison to the steam explosion pretreatment, ammonia fiber explosion (AFEX) subjects biomass material to liquid anhydrous ammonia under high pressures and lower temperatures (60°C to 100°C) and is then quickly depressurized (Brodeur et al., 2011). Another possibility is a CO₂ explosion pretreatment, a method analogous to steam and ammonia fiber explosion but requiring lower temperatures. High pressure CO₂ is injected into the reactor and then released by an explosive decompression. CO₂ forms carbonic acid when dissolved in water, increasing the hydrolysis rate (Harmsen et al., 2010). Ammonia recycle percolation (ARP) is a very similar process to the AFEX but requires higher temperatures (140 °C to 210 °C) and longer reaction times increasing energy costs (Brodeur et al., 2011).

Table 1 Advantages and disadvantages of different pretreatment technologies (adapted from (Hendriks & Zeeman, 2008; Taherzadeh & Karimi, 2008))

Pretreatment	Advantages	Disadvantages
Biological	low energy consumption	Slow, no lignin breakdown, continuous addition required, high cost of enzymes
Chemical		
Acidic pretreatment	solubilizes hemicellulose	high cost of acid, corrosion problems, formation of inhibitors, particularly with heat
Alkaline pretreatment	breaks down lignin	high alkali concentration in digester, high cost of chemicals
Physical	increases surface area, makes substrate easier to handle, often improves fluidity in digester	increased energy demand, high maintenance costs / sensitive to impurities
Combined processes		
Steam-Explosion	breaks down lignin and solubilizes hemicellulose	increased heat and electricity demand, only effective up to a certain temperature threshold
Hydrothermolysis	increases enzyme accessibility	increased heat and electricity demand, only effective up to a certain temperature threshold
Extrusion	increases surface area	increased energy demand, high maintenance costs/ sensitive to impurities

The various pretreatment methods prepare the biomass for digestion to varying degrees. Depending on the type of biomass undergoing pretreatment, these technologies can help achieve increases in specific biogas yield. The pretreatment methods mentioned above all have a significant influence on increasing the contact surface area. Table 1 compares the advantages and disadvantages of the various pretreatment technologies.

Pretreatment of biomass using steam explosion has three positive effects including an increase in contact area, the dissolution of hemicellulose, and the change in lignin structure. However, this pretreatment can also potentially form inhibitors such as furfural and hydroxymethylfurfural, which negatively influence organic degradation later in the process. The procedure and the chemical process of steam explosion are discussed in more detail in the following chapter.

STEAM EXPLOSION TECHNOLOGY

Steam explosion is currently one of the most intensively investigated pretreatment technologies for lignocellulosic materials in both ethanol and biogas production. Steam explosion has been proven to be an effective pretreatment method for both biogas and ethanol production using different input materials such as wood (Horn et al., 2011a), grasses (Prochnow et al., 2009), agricultural residues (Ballesteros et al., 2002; Bauer et al., 2009), by-products (De Paoli et al., 2011) and municipal waste (Li et al., 2007). Moreover, steam-explosion technology has reached full-scale commercialization.

Compared to alternative pre-treatment methods, the advantages of steam explosion include a remarkably low environmental impact, lower capital investment and less hazardous process chemicals (Li et al., 2001). Like other physicochemical pretreatment methods, however, it may create degradation products that have an inhibitory and toxic effect on anaerobic digestion. The composition and concentration of these inhibitors vary with the severity of the pretreatment, the raw material used, and the type and composition of chemical catalysts employed (García-Aparicio et al., 2006).

Description of the technology

An example of a laboratory-scale steam explosion plant is shown in Fig. 2.

The factors that most affect steam explosion pretreatment are temperature, residence time, particle size, and moisture content (Cara et al., 2008). The process entails treating the biomass at a temperature of 160 °C - 260 °C and under high pressure (0.7- 4.8 MPa). The treatment is applied for a specified duration (several minutes) before the pressure is abruptly reduced, causing the material to suffer an explosive decompression. This process enhances the hydrolysis of the hemicellulose into water-soluble oligomers or into individual sugars and generates an improved substrate for enzymatic hydrolysis by cellulases. The rupture of the lignin-carbohydrate union, combined with the hemicellulose solubilization, is responsible for the significant increase in polysaccharides degradable through enzymatic hydrolysis (Fernández-Bolaños et al., 2001). Furthermore, the rapid thermal expansion opens up the biomass particle structure leading to a reduction in particle size and an increase in pore volume (Michalowicz et al., 1991). In its simplest forms, this treatment requires no addition of chemicals (autohydrolysis).

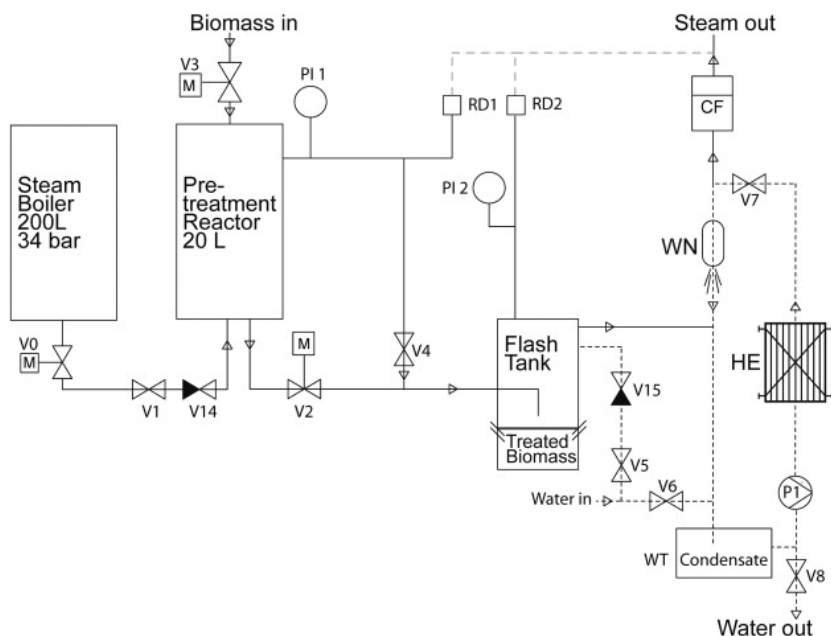


Fig. 2 Laboratory-scale steam explosion unit (CAMBI AS, Norway). “V” refers to valves and “M” to motorized valves (Horn et al. 2011b).

Steam explosion pretreatment effects on the chemical composition of selected biomasses

Steam explosion decreases the dry matter (DM) content of biomass due to the use of steam in the pretreatment. The use of steam adds water to the samples. In general terms, the DM content appears to be lower in samples treated for longer durations because the biomass is exposed to steam for a longer time. A considerable decrease in the DM content of hay was reported by Bauer et al. (2014). While the untreated biomass had a DM content of 87.1 %, this value decreased significantly in all treated samples, reaching a minimum value of 22.8 %. This value was obtained under the harshest conditions studied (220 °C for 15 minutes). Similar results have been obtained for miscanthus, where the initial DM content of untreated biomass (88.4 %) was significantly reduced after steam explosion to a minimum of 24 % (Menardo et al., 2012). Similar tendencies have been obtained for steam exploded birch, salix and bagasse (Agger et al., 2013).

Pretreating with steam explosion can also influence volatile solid (VS) content. In the study by Bauer et al. (2014) mentioned above, steam explosion decreased the original VS content of hay from 94.1 to 90.6 % (after pretreatment at 220 °C for 10 minutes). After pretreating miscanthus at 220 °C for 15 minutes, the decrease in VS was smaller, with a decrease from 97.9 to 97.3 % (Menardo et al., 2012). The loss of volatile substances (e.g. acetic acid, levulinic acid, formic acid or furan derivatives) in the outlet steam after the steam explosion is responsible for the reduction in the final VS content of the biomass. This reduction is more pronounced under harsh conditions.

Steam explosion only slightly influences the cellulose content of pretreated biomass. Menardo et al. (2012) analyzed the cellulose concentration of untreated and pretreated miscanthus samples. While untreated miscanthus has a cellulose content of 50.7% DM, the percentage of cellulose of pretreated miscanthus did not follow any clear tendency when the intensity of the pretreatment was increased, with values ranging from 48.1% to 55.2% DM. Similarly, the cellulose content of steam-exploded hay did not follow any trend when similar pretreatment conditions were applied (Bauer et al., 2014). The cellulose in the untreated hay sample was 34.9 % DM and its content after steam explosion ranged from 26.7 to 36.9 % DM. However, Horn et al. (2011b) reported a relative increase in the cellulose content for wheat straw after pretreatments at 210 °C.

In contrast, hemicellulose content is strongly affected by steam explosion. Menardo et al. (2012) reported a hemicellulose content of 27.5% DM for untreated miscanthus. Pretreating the miscanthus at 180°C for 5 minutes reduced the hemicellulose by about 15% compared to the untreated sample. At a temperature of 180°C, pretreatment times of 10 and 15 minutes resulted in a hemicellulose degradation of 19% and 55%, respectively. When temperatures over 200 °C were applied, the average hemicellulose content was lower than 2 %. In addition, increasing temperatures to above 200 °C and extending the pretreatment duration did not have significant effects on hemicellulose degradation. Similarly, steam explosion led to a progressive reduction in the content of hemicellulose from hay biomass with increasing pretreatment intensity (Bauer et al., 2014). The untreated hay sample had a hemicellulose content of 18.9 % DM. The harshest pretreatment conditions studied reduced the hemicellulose content by approximately 99 % in comparison to the untreated sample. These results are in accordance with Garrote et al. (1999), who reported that hemicellulose begins to solubilize at 150 °C.

Steam explosion pretreatment can also substantially affect lignin content, however effects follow no clear trend. Steam explosion pretreatment of miscanthus caused a lignin degradation of nearly 50% (Menardo et al., 2012). Untreated miscanthus had an initial acid detergent lignin (ADL) content of 15.6 % DM, which decreased to 7.9 % DM when the biomass was pretreated at 220 °C for 10 and 15 minutes. Similar decreases were obtained after steam explosion of eucalyptus (Martín-Sampedro et al., 2011), *Hesperaloe funifera* (Martín-Sampedro et al., 2012) and other plant biomass (Bobleter, 1994). However, many other studies have reported noticeable lignin increases after pretreatment with steam explosion. Bauer et al., (2014) measured increases in the ADL concentration of hay to 5.8 % DM after pretreatment at 220 °C for 15 min, up to four-fold the original value. Horn et al. (2011b) studied steam explosion of wheat straw at 210 °C for 10 min and measured increases in the Klason lignin of 44 %. In addition, steam exploded birch showed considerable accumulation of Klason lignin, increasing with the severity of the pretreatment (Vivekanand et al., 2013). According to Ramos et al., (2003) the more drastic the conditions used in the steam explosion pretreatment, the higher the relative amount of acid-insoluble lignin in the biomass.

The degradation of hemicelluloses and the increase in lignin content obtained after pretreatment with steam explosion can be attributed to the formation of pseudo-lignin, which is related to the degradation of hemicellulose sugars. The hydrolysis of hemicelluloses under the acidic conditions of steam explosion resulted in monosaccharides, leading to the formation of different degradation products (Nelson et al., 1988). These

degradation products may be transformed to acid-insoluble pseudo-lignin (Sannigrahi et al., 2011) and then measured as lignin. Ballesteros et al., (2004) reported slight increases in the acid-insoluble lignin content of herbaceous biomass caused by condensation and re-polymerization reactions.

All things considered, changes in the proportions of cellulose, hemicellulose and lignin cannot be easily predicted, as many variables influence the way biomass is affected by steam explosion.

Changes in biomass fiber morphology caused by steam explosion

Scanning electron microscopic analyses of native (untreated) samples and of samples pretreated at different conditions (190 and 220 °C with a retention time of 10 min) were carried out to assess alterations in the biomass fiber morphology (Fig. 3).

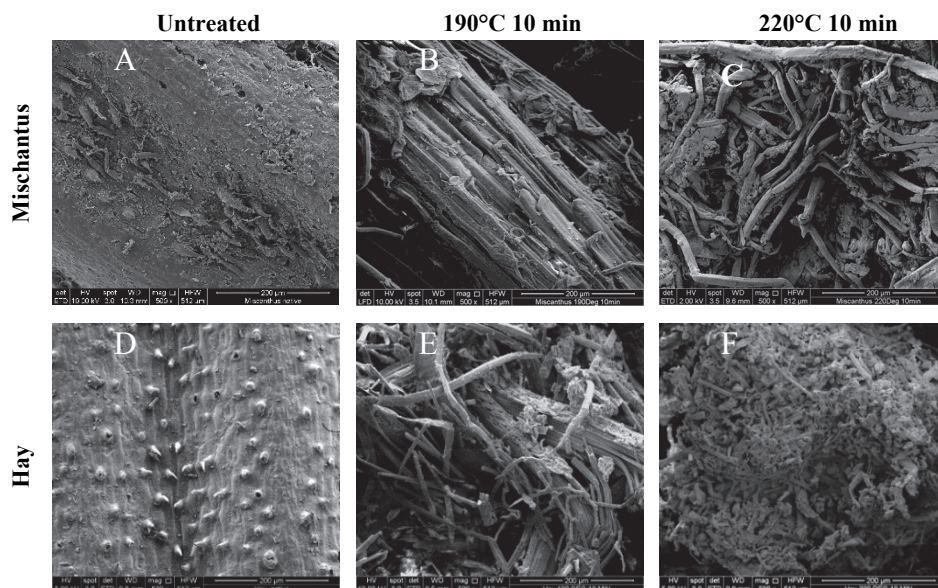


Fig. 3 Scanning electron micrographs of untreated and steam-exploded miscanthus and hay under magnification of 500x

The changes in the morphology caused by steam explosion are clearly visible after treatment at 190 °C and differ greatly depending on the type of biomass. While a slight disruption is observed in miscanthus (Fig. 3B), the same treatment intensities applied to hay induced a substantial defibrillation effect, consisting of a separation of individual fibers (Fig. 3E). This effect may be due to the solubilization of cementing materials (mainly lignin and hemicellulose). Substantial changes are observed after steam explosion at 200 °C. While a notable defibrillation effect was observed in miscanthus (Fig. 3C), the same intensities applied to hay led to more intense morphological changes (Fig. 3F), with the development of an amorphous structure and the formation of agglomerates. These effects of

steam explosion on biomass are typical and have been previously reported by other authors for different materials (Kristensen et al., 2008; Schultz et al., 1983).

3.4. Effect of steam explosion pre-treatment on the specific methane and biogas yields

Steam explosion is a pretreatment technology that has the potential to increase the biogas yield of lignocellulosic biomass (Clark & Mackie, 1987). Menardo et al., (2012) demonstrated that pretreating miscanthus with steam explosion increased the methane yield of untreated biomass from 84 to 374 l_N kg⁻¹ VS. The effect on methane yields was well correlated with the intensity of the pretreatment conditions and the best outcome was obtained after a pretreatment at 220 °C for 10 min. Harsher conditions did not positively affect the methane yield. Similar pretreatment intensities were suggested by Vivekanand et al. (2012) for birch. While untreated birch provided 204 l_N kg⁻¹ VS, steam explosion at 220 °C for 10 min increased the yield to 369 l_N kg⁻¹ VS.

De Paoli et al. (2011) also reported significant increases in methane yield. Their study compared methane production from non-treated straw and from straw that underwent steam explosion under different degrees of severity. While untreated material produced 79 l_N kg⁻¹ VS, the optimum pretreatment conditions were 190 °C for 15 min, which increased yields up to 229 l_N kg⁻¹ VS.

Bauer et al. (2009) investigated the effects of steam explosion on wheat straw. While the ground, non-steam-exploded straw yielded 276 l_N kg⁻¹ VS, steam-exploded biomass reached 331 l_N kg⁻¹ VS after a pretreatment at 180 °C for 10 minutes. On the other hand, a study by Bauer et al. (2014) reported smaller methane increases for steam-exploded hay. While the specific methane yield of untreated hay was 243 l_N kg⁻¹ VS, steam explosion at 175 °C for 10 min increased the methane yield only by 16 %, to a total of 281 l_N kg⁻¹ VS. Harsher conditions resulted in substantially lower specific methane yields. The reason for this reduction under severe pretreatment conditions was attributed mainly to the formation of substances inhibiting the microorganisms responsible for the anaerobic digestion process (e.g. phenolic compounds or furan derivatives) as well as to the loss of sugars due to pseudo-lignin formation.

Hence, the required steam explosion conditions depend to a great extent on the type of biomass being treated. Therefore, steam explosion trials with a specific target biomass are of great importance in order to optimize the pretreatment and subsequent fermentation processes.

ENVIRONMENTAL LIFE-CYCLE ASSESSMENT OF BIOGAS WITH STEAM EXPLOSION PRETREATMENT

Using the well-established method of life-cycle assessment (LCA), potential environmental impacts of biogas production can be quantified and analyzed. Bachmaier et al. (2013) used this approach to calculate the energy consumption and greenhouse gas emissions of 16 different Bavarian biogas plants showing the effects of variations in input substrates, plant sizes and plant design. A similar study by Laaber (2011) compared 41 Austrian biogas plants. These studies show that electricity from biogas can compare favorably to conventional electricity mixes if co-products are used efficiently and if the biogas plant is operated with minimal losses of methane. The LCA of biogas in general has

been extensively studied (Börjesson & Berglund, 2006; Poeschl et al., 2012; Whiting & Azapagic, 2014). However, little is known about biogas systems that use steam explosion pretreatment to enhance fermentation of poorly-digestible biomass. For dedicated energy crops (maize silage and triticale grain), Schumacher et al. (2010) compared environmental impacts of biogas production with and without steam explosion, among other biofuel options. A pronounced increase in heat demand due to steam explosion pretreatment outweighed a slight increase in biogas energy output, leading to higher environmental impacts for the steam explosion pretreatment. To the knowledge of the authors, similar comparisons for agricultural residue substrates such as maize stover have not been published.

In a recent study by Kral et al. (in preparation), the environmental impacts of biogas electricity from agricultural residues (maize stover) with steam explosion pretreatment were compared to those of a typical Austrian biogas system (maize silage and manure). The pretreatment/residue scenario resulted in lower total climate change impacts than those of the typical biogas system (252 g CO₂eq per kWh_{el} vs. 299 g CO₂eq per kWh_{el}; 100-year global warming potential, GWP). Methane slip emissions of 147 g CO₂eq per kWh_{el} from the CHP unit exhaust account for the largest GWP share in both scenarios. Other large GWP contributions are from substrate production and grid electricity for plant operations.

In another study by Saylor et al. (in preparation), the same biogas plant model is incorporated into a larger agro-municipal system: the current waste management and energy system in an Alpine municipality of Western Austria is compared to a hypothetical system that uses hay from currently unused alpine grassland as the main substrate in a local biogas plant. With respect to the overall global warming potential, the hypothetical local biogas plant compares favorably to the existing system, with 0.451±0.027 kg CO₂eq per kWh_{el} generated electricity versus 0.378±0.099 kg CO₂eq per kWh_{el} in the current system. Here, the relative environmental impacts depend strongly on the fossil fuels that the local biogas plant is assumed to displace; methane slip emissions from the exhaust are another critical contributor to the overall global warming potential.

These results demonstrate clearly that steam explosion pre-treatment of agricultural residues and their subsequent use as biogas substrates can help to lower the environmental impacts of energy production from biogas.

POTENTIAL ANALYSIS OF CROP RESIDUES INCLUDING LIMITATIONS IN THE EUROPEAN UNION

Agricultural crop production generates significant amounts of organic residues, a portion of which remains on the field after harvesting. Estimates on the quantities of crop residues that can be used for bioenergy production must take into account crop and residue production, environmental constraints for residue collection, and competing uses (Edwards, 2005). Despite their diminished organic degradability, a large economic potential lies in lignocellulosic biomass, such as straw that accrues during the cultivation of wheat, oil crops and various other crops. Potential studies are used to estimate biomass quantities. When conducting such studies, it is particularly important to clarify the term “potential”, as it possesses several relevant meanings. Depending on the specific context, “potential” may

convey information ranging from the availability of resources to their degree of usability with consideration of local conditions.

Kaltschmitt and Hartmann (2001) elaborate on the various possible definitions of the term “potential.” Table 2 gives definitions of the five types of potentials used to estimate biomass availability. *Theoretical potential* indicates the upper limit of the feasible contribution to energy production, however in practice it can never be exploited in its entirety. In contrast to *theoretical potential*, *economic potential* is associated with a high degree of uncertainty. Furthermore, in comparison to the *technical potential*, *economic potential* can fluctuate significantly over time depending on location (Kaltschmitt & Hartmann, 2001).

Table 2 Types of crop residue potentials

Theoretical potential	Entire produced crop residues
Technical potential	Technically harvestable rate
Economic potential	Economically viable harvestable rate including competing uses
Implementation potential	Feasible potential under concrete socio-political framework conditions, including economic, institutional and social constraints and policy incentives
Sustainable implementation potential	Sustainably available utilization potential integrating environmental, economic and social sustainability criteria for biomass resource

As no statistical data was available on the quantities of various crop residues, estimates were based on crop production data. Using the residue-to-grain ratio, biomass residues were derived. Both this ratio and the Harvest Index vary substantially depending on crop type, plant variety, climate and soil conditions, and farming practices (Kaltschmitt et al., 2009; Panoutsou et al., 2009; Scarlat et al., 2010). The production of major agricultural crops, with a focus on maize, rapeseed and sunflower, was based on data from EUROSTAT for the period of 10 years (2001-2010) in Europe (EU 27).

The removal rate of crop residues is an issue that has been debated for decades. In order to estimate sustainable removal rates, environmental constraints have to be carefully considered, among others. Partial removal of agricultural residues has proven possible, while avoiding soil degradation and depletion of soil organic matter and maintaining soil fertility (Ericsson & Nilsson, 2006). The appropriate rate of residue removal should be calculated according to the minimum residues necessary to keep soil quality and avoid erosion (Johnson et al., 2006). Moreover, it must be taken into account that nutrient removal can be mitigated with appropriate crop rotations, the implementation of conservation tillage and by applying fermentation residues generated in biogas plants to agricultural fields. Several studies have estimated sustainable crop residue collection, generally varying from 30 % to 60 % (Glassner et al.; Kadam & McMillan, 2003; Nikolaou et al., 2003; Walsh & R.L., 2000).

In order to calculate the sustainable crop potential, the technically harvestable and ecologically justifiable rate was estimated based on literature data (Scarlat et al., 2010). The

competing uses of crop residues for animal husbandry, for mushroom production, as a raw material for construction and other industries, as well as for energy production via combustion were considered when estimating biomass availability (Kaltschmitt et al., 2009; Panoutsou et al., 2009; Scarlat et al., 2010). Future uses and demand increases for currently unused biomass sources were also projected.

The potential estimate for the EU 27 was calculated according to the definitions given by Kaltschmitt (2009) and BEE (2011). An estimate of the biomass crop residue potential (Bp) available in each EU member state (subscript i) was calculated based on the following formula:

$$Bp_i = A_i Y_i R_i U_i, \text{ where}$$

Bp_i is a country's crop residue biomass potential (t), A_i the harvested crop area (ha), Y_i the yield of the main product (t/ha), R_i the residue-to-grain ratio and U_i the sustainable utilization rate (considering harvesting, environmental constraints and competing uses).

The total sustainably available crop residue potential (Bpt) was obtained by adding the potentials from selected crops produced in each state (subscript j):

$$Bpt = \sum_j Bp_j = \sum_j \sum_i A_i Y_i R_i U_i$$

Biomass supply security plays an important role for technology deployment and long-term investment (Panoutsou et al., 2009; Scarlat et al., 2010). Therefore, the volatility of crop residue supply must be considered. Based on 10 years of data, the yearly available biomass has been calculated to estimate the market potential and supply risk. Furthermore, in order to estimate the crop residue supply for the next 10-20 years, future production developments must also be considered for the selected crops.

The main agricultural crops in the EU 27 produced an average of 288 Mt of grain over 10 years. The production potential of crop residues corresponds to around 275 Mt of dry matter annually. The residue-to-grain ratios reported in the literature vary significantly (Kaltschmitt et al., 2009; Panoutsou et al., 2009; Scarlat et al., 2010). The ratios applied for the main crop residues (referred to by Scarlat (2010)) are quite conservative.

Table 3 Sustainably available main agricultural crop residues in the EU 27, average over 10 years

Agricultural crop residues	Sustainably available crop residues (Mt DM)
Wheat	53.98
Barley	20.97
Maize (corn)	20.64
Rapeseed	7.84
Sunflower	5.05
Rye / Oats / Rice	8.50
Grand total	116.98

The rate of sustainably available crop residues in the EU (see Table 3), considering environmental and harvesting constraints, as well as other competing uses for biomass, corresponds to an average of 117 Mt dry matter per year based on the assumption that 40 or 50 % of the crop residues (depending on the crop) can be used for bioenergy production (Scarlat et al., 2010). Notably, wheat, barley and maize straw constitute 82 % of the total sustainable crop residues potential.

CONCLUSION AND FURTHER INVESTIGATIONS

Lignocellulosic biomass from agricultural residues represents an unutilized (or at least under-utilized) but promising resource for biogas production. The lignocellulosic complex that dominates the residue composition creates a protective barrier that limits its utilization in anaerobic digestion processes. Thus, efficient biomass conversion requires the implementation of a pretreatment step. Amongst the many different pretreatment options, appropriate selection depends on the chemical composition of the original biomass as well as the specific requirements of biogas plants, including reactor design and size, applied retention times, and economic factors. For biomass with a soft lignocellulosic complex (e.g. maize straw or hay) a simple process such as mechanical pretreatment can be an appropriate solution that does not create any inhibiting substances for microorganisms. On the other hand, highly lignocellulosic biomass (e.g. miscanthus, willow, wheat straw or biomass from protected areas) requires harsher pretreatment processes such as steam explosion. The utilization of steam explosion with strong lignocellulosic biomass has been reported to improve the digestion process as well as to substantially increase the specific methane yield in comparison to untreated biomass. Moreover, increasing the severity of the steam explosion pretreatment leads to greater disruption and defibrillation of the biomass structure and a substantial decrease in hemicellulose content. In some cases, substantial production of pseudo lignin has been reported. However, the pretreatment's effect on chemical composition depends to a greater extent on the composition of the biomass. With regard to environmental sustainability, two recent case studies demonstrate benefits of residue utilization for biogas with steam explosion treatment in several critical environmental impact categories. Further development of more cost-efficient and energy-efficient pretreatment technologies is still needed. Special focus should be put on decreasing the formation of inhibitors as well as on improving the energy efficiency of the pretreatment step. Overall, estimates by the authors indicate the potential availability in Europe of large amounts of agricultural residual biomass, dominated by barley, wheat, and maize straw. Research into the further development and sustainable implementation of appropriate pretreatment technologies could play a critical role in developing this valuable energy resource over the next decades.

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BIOPLINSKE NAPRAVE V SLOVENIJI - PROBLEMI IN PRILOŽNOSTI

TOMAŽ POJE

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IZVLEČEK

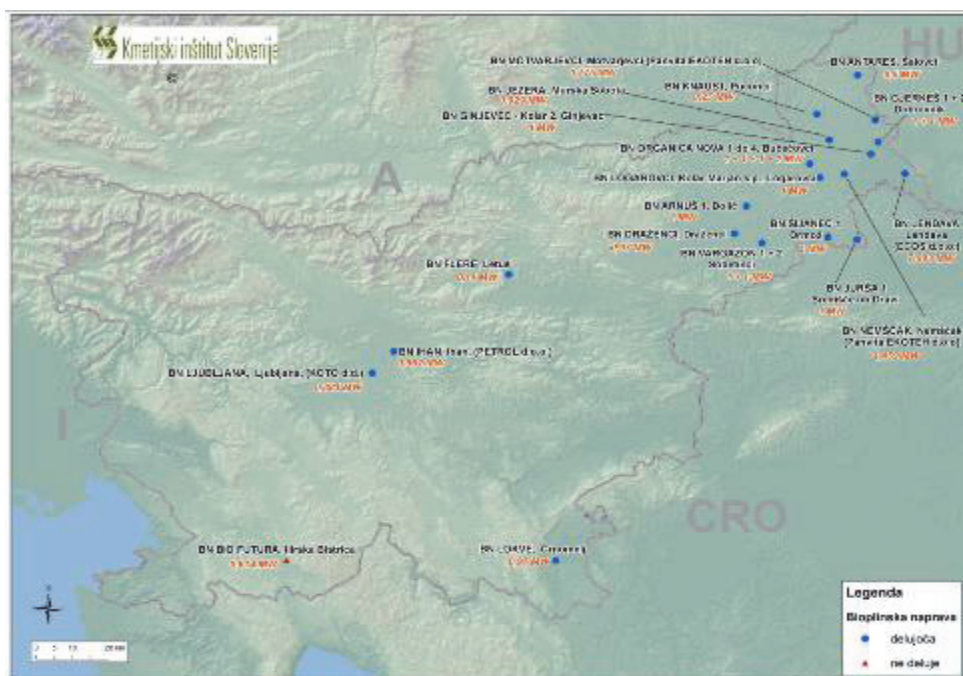
V Sloveniji imamo leta 2014 štiriindvajset bioplinskih naprav s skupno nazivno močjo 27,6 MW_{el}. Bioplin se uporablja le za proizvodnjo električne energije, toplotna energija pa se premalo izkorišča. V letu 2013 so bioplinske naprave proizvedle 106225,7 MWh električne energije, kar je manj kot leto prej, saj ni bilo dovolj vhodnih substratov zaradi suše. Trenutno zaradi sistema podpor, ki omejuje rabo poljščin, ni zanimanja za gradnjo novih bioplinskih naprav. Kmetijski potencial in posestna struktura pa predstavlja možnost za gradnjo novih mikro in malih bioplinskih naprav. To bo še bolj izrazito, če bo država povečala podporo za uporabo živinskih gnojil ali če bodo ponudniki bioplinskih tehnologij znižali cene. Sosedje in civilne iniciative pa velikokrat upravičeno pa tudi neupravičeno oznanjajo družbeno nesprejemljivost starih in novih bioplinskih projektov.

Ključne besede: bioplin, stanje, proizvodnja električna energije, podpore, male bioplinske naprave, Slovenija

UVOD

Po podatkih Javne Agencije Republike Slovenije za energijo [1] imamo oktobra 2014 štiriindvajset bioplinskih naprav z deklaracijami in s skupno nazivno električno močjo 27,6 MW_{el}. Največja bioplinska naprava je bioplinska naprava ECOS d.o.o. v Lendavi, z nazivno močjo 7 MW_{el}. Najmanjša bioplinska naprava je bioplinska naprava Bioterm d.o.o. na kmetiji Flere v Savinjski dolini, ki ima deklaracijo za proizvodno napravo za 110 kW_{el}. Bioplinska naprava Petač v Zgornjih Pirničah je bila sicer zgrajena, ni pa nikoli delovala, sedaj je v fazi razgradnje. Po dostopnih informacijah tudi bioplinska naprava v Ilirski Bistrici že nekaj let ne deluje. Nekatere bioplinske naprave so v zadnjih letih zamenjale lastnike, nekatere so bile oddane v najem. Na karti je prikazana nazivna električna moč kogeneratorskih naprav.

Nekaj na karti prikazanih bioplinskih naprav je pogojno kmetijskih, ker v večjem deležu uporabljajo tudi substrate, ki ne izvirajo iz kmetijstva. Nekatere bioplinske naprave pa so tudi že pridobila ali pa pridobivajo ustrezna okoljevarstvena dovoljenja za uporabo substratov, ki ne izvirajo iz kmetijstva. Poleg kmetijskih bioplinskih naprav imamo v Sloveniji bioplinske naprave na centralnih čistilnih napravah in na deponijah, ki izkoriščajo deponijski plin, ki pa jih na karti nismo prikazali.

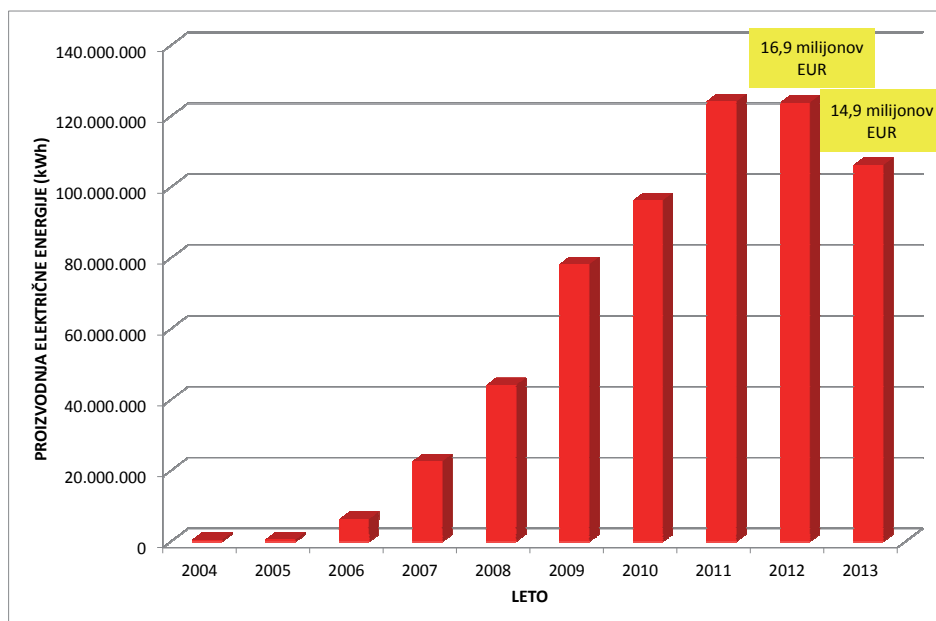


Slika 1 Karta (kmetijskih) bioplinskih naprav
Fig. 1 Map of farm biogas plants

UPORABA BIOPLINA

Zaradi sistema podpor se bioplin v Sloveniji uporablja za proizvodnjo (in prodajo) električne energije v kogeneratorskih enotah. Pri kogeneraciji bioplina nastaja električna energija in toplota. Zlasti na področju uporabe toplote izven bioplinske naprave je še premalo storjeno, saj le nekaj bioplinskih naprav koristno oddaja toploto zunanjim porabnikom. Z oddajanjem toplote pa se povečajo prihodki bioplinske naprave. Dosedanji sistem podpor pa je bil vezan le na proizvodnjo električne energije, in tudi ekonomska upravičenost gradnje se je računala glede na (subvencionirano) ceno električne energije proizvedene iz bioplina. Predelan substrat (digestat) se v Sloveniji uporablja na najbolj preprost način kot organsko gnojilo za kmetijske površine. Nihče tega produkta ne predeluje na primer v kompost, specialna organska gnojila, pelete za gorivo, kar bi povečalo dodano vrednost produktu.

Seveda vse bioplinske naprave ne delajo s »polno« močjo ampak v odvisnosti od količine vhodnih substratov in od poteka anaerobne fermentacije. Suša je v Sloveniji v preteklih letih bistveno zmanjšala pridelke koruze, s tem pa je tudi proizvodnja električne energije iz bioplinskih naprav, ki uporabljajo koruzo kot enega izmed glavnih vhodnih substratov, stagnirala. V grafu predstavljamo podatke BORZEN-a [2] o proizvodnji električne energije iz bioplina od leta 2004 do 2013 ter višino izplačil za proizvedeno elektriko.



Graf 1 Proizvodnja električne energije iz bioplina
Graph 1 Electricity production from biogas

PODPORA ELEKTRIČNI ENERGIJI PROIZVEDENI V BIOPLINSKIH NAPRAVAH

Na temelju Uredbe o podporah električni energiji proizvedeni iz obnovljivih virov energije imamo v Sloveniji podporo električni energiji proizvedeni v bioplinskih napravah v obliki:

- zagotovljenega odkupa električne energije,
- finančne pomoči za tekoče poslovanje (obratovalna podpora).

Višina zagotovljenega odkupa je enaka referenčni ceni, ki je sestavljena iz fiksne in spremenljivega dela. Referenčna cena se spreminja najmanj enkrat letno.

Za bioplin proizveden iz biomase (B1 in B2 substrati) so izplačilo lahko poveča zaradi bonusov za večji delež gnojevke ali oddajanje toplote.

Zakonodajalec je s spremembo Uredbe o podporah električni energiji leta 2011 bistveno spremenil pogoje za bioplinke naprave, tako da je za nove bioplinke naprave omejil uporabo energetskih rastlin – glavnih poljščin. Navedene spremembe so nastale na predlog tedanjega Ministrstva za kmetijstvo, gozdarstvo in prehrano, ki se je tako kot Evropska skupnost začela zavedati problematike zagotavljanja prehranske varnosti na nivoju države. Te zakonodajne spremembe so zreducirale interes investitorjev v gradnjo novih bioplinških naprav. Do tedaj zgrajene bioplinke naprave pa delujejo po pogojih ob podpisu pogodbe za odkup električne energije (niso omejene z uporabo koruze).

Tabela 1 Višina zagotovljenega odkupa za električno energijo proizvedeno iz bioplina za leto 2014.; B1 so energetske rastline, B2 so biorazgradljive frakcije izdelkov, ostankov in odpadkov iz kmetijstva. C1 in C2 so biološko razgradljivi komunalni in industrijski odpadki

Table 1 Guaranteed purchase price for electricity produced from biogas in 2014; B1 – energy crops; B2 – biodegradable fractions of products, waste and residues from agriculture; C1 and C2 – biodegradable municipal and industrial waste

Velikostni razred bioplinke naprave	Zagotovljeni odkup (EUR/MWh _{el})	
	B1 in B2 vhodni substrati	C1 in C2 vhodni substrati
Mikro (do 50 kW)	165,55	139,23
Mala (do 1 MW)	161,75	139,23
Srednja (do 10 MW)	147,77	129,15

Tabela 2 Višina obratovalne podpore za električno energijo proizvedeno iz bioplina za leto 2014.; B1 so energetske rastline, B2 so biorazgradljive frakcije izdelkov, ostankov in odpadkov iz kmetijstva. C1 in C2 so biološko razgradljivi komunalni in industrijski odpadki

Table 2 Subsidies for electricity produced from biogas in 2014; B1 – energy crops; B2 – biodegradable fractions of products, waste and residues from agriculture; C1 and C2 – biodegradable municipal and industrial waste

Velikostni razred bioplinke naprave	Obratovalna podpora (EUR/MWh _{el})	
	B1 in B2 vhodni substrati	C1 in C2 vhodni substrati
Mikro (do 50 kW)	127,44	101,12
Mala (do 1 MW)	122,34	99,82
Srednja (do 10 MW)	107,92	89,30

ZDRUŽENJA LASTNIKOV BIOPLINSKIH NAPRAV

Lastniki bioplinskih naprav so v zadnjih letih ustanovili tri stanovska združenja za lažje uresničevanje svojih ciljev [6]. Leta 2008 je bilo ustanovljeno »Združenje proizvajalcev bioplina«, ki je bilo aktivno zlasti pri pripravi nove Uredbe o podporah OVE, ki je bila sprejeta leta 2009. V letu 2012 je bil ustanovljen "GIZ Bioplin" - gospodarsko interesno združenje v katerem so bioplinske naprave zgrajene po Keter Organica tehnologiji. V okviru Gospodarske zbornice Slovenije (GZS) - Zbornice kmetijskih in živilskih podjetij (ZKŽP) pa so 19. novembra 2012 ustanovili Sekcijo bioplinarjev, ki predelujejo organske odpadke z namenom pridobivanja bioplina. Osnovni cilj delovanja Sekcije je strokovno in interesno povezovanje, z namenom izboljšanja in spodbujanja gospodarske dejavnosti teh podjetij ter zagotavljanje njihove konkurenčnosti. Sekcija je bila v letu 2012 najbolj aktivna na področju Uredbe o predelavi biološko razgradljivih odpadkov. Vsa ta združenja so dejavna predvsem takrat, ko zagovarjajo svoje interese.

VELIKOSTNA STRUKTURA BIOPLINSKIH NAPRAV

Število kmetijskih bioplinskih naprav je v Sloveniji do leta 2011 rastlo kljub že prisotni gospodarski recesiji. Zasluga je v državnih podporah obnovljivim virom energije, kamor spada tudi elektrika proizvedena iz bioplina. Povečini so se zgradile velike bioplinske naprave (povprečna velikost 1 MW_{el}). Spremembe v sistemu podpor, ki so omejile rabo energetskih rastlin za proizvodnjo bioplina, pa so zmanjšale interes investitorjev za gradnjo novih bioplinskih naprav. Slovenija je leta 2010 sprejela Akcijski načrt za obnovljive vire energije za obdobje 2010 – 2020 (AN OVE). V njem je načrt za l. 2014, da bomo imeli za 40 MW_{el} bioplinskih naprav. Zgrajenih pa imamo 24 delujočih bioplinskih naprav z deklaracijami in s skupno nazivno električno močjo 27,6 MW_{el} [5, 6].

Ko govorimo o velikosti (kmetijske) bioplinske naprave, potem bioplinski strokovnjaki pravijo, da je njena velikost odvisna od razpoložljivega substrata, še bolj pa od razpoložljivih kmetijskih površin za trosenje predelanega substrata (digestata) iz bioplinske naprave. Vhodna surovina lahko namreč pride v bioplinsko napravo tudi od drugod. Pri trosenju predelanega substrata pa obstajajo zahteve (omejitve) vezane na količino dušika na hektar in na količino morebitnih težkih kovin v predelanem substratu.

Nadaljnji razvoj (kmetijskih) bioplinskih naprav v Sloveniji je odvisen od:

- sistema podpor države (ali posameznih ministrstev),
- kmetijskega potenciala.

Po scenariju, ki najmanj posega v primarno kmetijsko pridelavo, je kmetijski potencial za bioplin 86 MW_{el} [7]. Sistem podpor pa mora biti stabilen, tako da investitorji vedo v kašnih razmerah bodo poslovali. Sistem podpor bi moral bolje podpreti mikro in male bioplinske naprave, ki bi kot glavni substrat uporabljale živinska gnojila. Kmetje v Sloveniji morajo 6 mesecev skladiščiti gnojevko. Ob tem pa nekontrolirano nastaja metan. Zaradi zaveze države, da bo zmanjšala toplogredne pline, mora svoje prispevati tudi kmetijstvo. In to bo v Sloveniji zaradi njene kmetijske lastniške strukture (povprečna kmetija ima 6,4 ha) možno samo z mikro in malimi bioplinskimi napravami na živinska gnojila [3]. Gradnja mikro in malih kmetijskih bioplinskih naprav v Sloveniji bo zaživila,

če bodo podpore za te kategorije bioplinskih naprav višje, kot so v trenutnem sistemu podpor, ali če bodo ponudniki tovrstnih bioplinskih naprav zmanjšali nabavno ceno. Tudi Ministrstvo za kmetijstvo, gozdarstvo in prehrano podpira pridobivanje bioplina iz živinskih gnojil in rastlinskih odpadkov, subvencionira celo gradnjo bioplinskih naprav. Vendar za to ni pravega zanimanja, saj potem odkupna cena za elektriko ni več 100 % ampak se glede na višino subvencije ustrezno zmanjša.



Slika 2 Prva mikro bioplinska naprava v Sloveniji, je produkt podjetja Omega Air iz Ljubljane. Postavljena pa je na Kmetijskem inštitutu Slovenije, za vhodni substrat pa uporablja gnojevko

Fig. 2 First micro biogas plant in Slovenia is a product of Omega Air company from Ljubljana; It is placed at the Agricultural Institute of Slovenia, and the input is slurry

DRUŽBENA SPREJEMLJIVOST BIOPLINSKIH NAPRAV

V Sloveniji so imeli investitorji kar precej problemov pri umeščanju svojih bioplinskih naprav v okolje. Sosedje, nevladne organizacije, civilne iniciative so velikokrat upravičeno pa tudi neupravičeno nasprotovale gradnji določenih bioplinskih naprav. Tudi mediji običajno sporočajo samo negativne vesti. Tako, da je tudi splošno javno mnenje dokaj proti bioplinskim napravam, še zlasti velikim, ki so ali še uporabljajo koruzno silažo kot glavni substrat.

ZAKLJUČEK

Gradnja večjih bioplinskih naprav v Sloveniji je obstala leta 2012 zaradi spremembe v sistemu podpor električni energiji (omejena je bila raba glavnih poljščin). Kljub tehnično dovršenim bioplinskim napravam pa je v zadnjih letih proizvodnja električne energije stagnirala, kajti suša je bistveno zmanjšala pridelek koruze, ki se uporablja kot eden glavnih substratov. Glede na posebno strukturo ne pričakujemo več gradenj velikih (1MWe) bioplinskih naprav. Zaradi zmanjšanja toplogrednih plinov v kmetijstvu, bo potrebno graditi mikro in male bioplinske naprave, ki bodo kot glavni substrat uporabljale živinska gnojila. Kmetje pa se bodo odločali za gradnjo, če bodo take bioplinske naprave boljše podprte ali če bodo ponudniki tehnologij znižali cene. Javnost pa samo gradnjo in potem tudi delovanje pogosto upravičeno, pa tudi neopravičeno smatra za družbeno nesprejemljive projekte.

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BIOGAS PLANTS IN SLOVENIA - PROBLEMS AND OPPORTUNITIES

ABSTRACT

In 2014 we have in Slovenia 2014 biogas plants with a total nominal power of 27.6 MWe. Biogas is used for the production of electricity, heat energy is

underutilized. In 2013 the biogas plants produced 106225,7 MWhe, which is less than the year before, because there was not enough input substrates due to the drought. Currently, due to the support system, which limits the use of crops, there is no interest for the construction of new biogas plants. Agricultural potential and property structure represents an opportunity to build new micro and small biogas plants. This will be even more pronounced if the state will increase its support for the use of animal manure or if the providers of biogas technologies lower prices. Neighbors and civil initiatives often justified as well as unjustified speak about social unacceptability of old and new biogas projects.

Key words: *biogas, status, power generation, support, small biogas plants, Slovenia*



SIDA HERMAPHRODITA KAO KULTURA ZA PROIZVODNJU ENERGIJE

NIKOLA BILANDŽIJA, MISLAV KONTEK, NEVEN VOĆA, TAJANA KRIČKA,
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SAŽETAK

*Obnovljivi izvori energije predstavljaju energetske resurse koji se koriste za proizvodnju električne i/ili toplinske energije, a čije rezerve se konstantno ili ciklički obnavljaju. Pod klasifikacijom obnovljivih izvora energije ubraja se i biomasa dobivena uzgojem kultura za proizvodnju energije. Cilj uzgoja brzorastućih kultura je proizvodnja, što je moguće veće, količine biomase po jedinici površine s ciljem njene pretvorbe u energiju. Energetske kulture mogu biti jednogodišnje ili višegodišnje biljke. Za razliku od jednogodišnjih, višegodišnje energetske kulture nemaju veće zahtjeve tijekom uzgoja i to prvenstveno u smislu agrotehnike i kvalitete poljoprivrednog tla. Mogućnost uzgoja na tlima lošije kvalitete je izuzetno bitno kako bi se izbjegla kolizija u proizvodnji energije i hrane. Jedna od takvih višegodišnjih kultura je i vrsta *Sida hermaphrodita*. Neke od osnovnih karakteristika navedene kulture su: visoki prinos suhe tvari (10 – 25 t/ha), visoka energetska vrijednost (18 MJ/kg), povoljan lignocelulozni sastav te niski zahtjevi i niska početna ulaganja tijekom uzgoja. U suradnji s OPG-om „EKO-Sever“ Agronomski fakultet u Zagrebu je 2014. započeo s istraživanjem kulture *Sida hermaphrodita*.*

Ključne riječi: obnovljivi izvori energije, kulture za proizvodnju energije, biomasa, *Sida hermaphrodita*

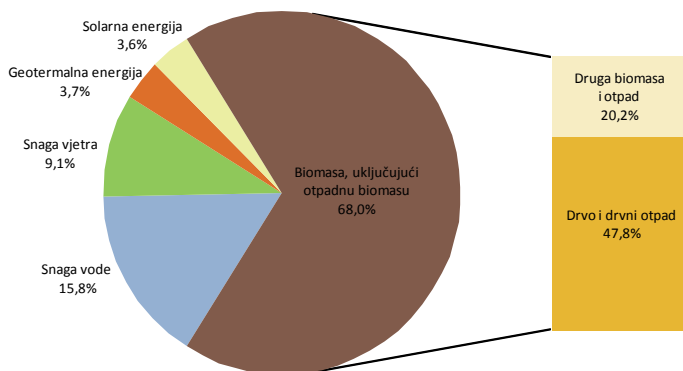
UVOD

Najosnovnije ljudske potrebe, kao i sve gospodarske i izvan gospodarske djelatnosti i aktivnosti, zahtijevaju potrošnju energije (Herceg, 2013.). Energija danas predstavlja jedan od najvažnijih pokazatelja ekonomskog i društvenog razvoja, te je prioritet svim zemljama svijeta još od ranih 70-ih godina prošlog stoljeća (Unal i Alibas, 2007.). Da je čovječanstvo više no ikada ovisno o potrošnji energije, govori podatak da je čak 65 000 MJ energije, na godišnjoj razini, potrebno po glavi stanovnika zemlje (Đonlagić, 2005.). Temeljem energet-

skih scenarija (smanjenje zaliha neobnovljivih izvora energije) i energetske težnje (sigurna, održiva i kontinuirana opskrba energijom) u sljedećih desetak godina očekuje se povećani rast proizvodnje i potrošnje obnovljivih izvora energije na globalnoj razini (van Dam i sur., 2008.; Tomić i sur., 2008.; Višković, 2009.). Nadalje, intenzivno i nekontrolirano korištenje fosilnih izvora energije dovelo je do ozbiljnih ekoloških posljedica s kojima se danas suočavamo (NEP, 1998.), pri čemu je izgaranje fosilnih energenata definirano kao jedno od najznačajnijih izvora onečišćenja okoliša.

Obnovljivi izvori energije predstavljaju energetske resurse koji se koriste za proizvodnju električne i/ili toplinske energije, a čije se rezerve stalno ili ciklički obnavljaju. Sam naziv obnovljivi, potiče od činjenice da se određena količina energije troši u iznosu koji ne premašuje brzinu kojom se ona nanovo stvara u prirodi. Obnovljivi ili tzv. neiscrpnici izvori energije na Zemlji dijele se na: energiju vjetra, geotermalnu energiju, energiju vode, energiju sunčevog zračenja, te energiju biomase (slika 1.), a potiču iz tri primarna izvora: raspadanja izotopa u dubini Zemlje, gravitacijskog djelovanja planeta i termonuklearnih pretvorbi na Suncu (Donlagić, 2005.; Šljivac i Šimić, 2008.).

Povećanje udjela obnovljivih izvora energije povećava energetske održivost cjelokupnog sustava, te ujedno pomaže u poboljšanju sigurnosti dostave energije i to na način da smanjuje ovisnost uvoza energetske sirovine i električne energije (Čakija, 2007.). U Europskoj uniji je tijekom 2011. godine ukupna potrošnja obnovljivih izvora energije iznosila 10%, u odnosu na ukupnu potrošnju svih fosilnih energenata. Temeljem podataka prikazanih na slici 1., najveći udio potrošene „zelene“ energije proizašao je iz biomase (68%), dok se ostali izvori obnovljive energije kreću u razmjeru od 3,6% (solarna energija) do 15,8% (energija vode) (AEBIOM, 2013.).



Slika 1 Potrošnja obnovljivih izvora energije u Europskoj uniji 2011. godine (AEBIOM, 2013.)

Osim s energetskeg aspekta, obnovljivi izvori energije imaju važnu ulogu u smanjivanju emisija stakleničkih plinova (poglavito CO₂) u atmosferu, što predstavlja jednu od ključnih smjernica Europske unije (Čakija, 2007.). U 2014. godini Europska komisija proširuje Energetsku strategiju za Europu do 2020. godine (2009/28/EC) te navodi ciljeve i scenarije do 2030. godine, propisivanjem Okvira za klimatske i energetske politike. Navedenim

Okvirom predlaže se smanjenje emisija stakleničkih plinova za 40%, povećanje udjela obnovljivih izvora energije od najmanje 27%, kontinuirano poboljšavanje energetske učinkovitosti, te osiguranje konkurentne, pristupačne i sigurne energije.

Kako je prikazano na slici 1., poljoprivreda uz šumarstvo, predstavlja najznačajniji prirodni resurs za proizvodnju obnovljive „zelene“ energije. Biogoriva su jedan oblik obnovljivih izvora energije koji se proizvode iz prirodnih (biljnih) materijala, a koja se mogu koristiti kao nadomjestak za benzin, naftu i naftne derivate. Pojam biogoriva obuhvaća kruta, tekuća i plinovita goriva koja se pretežno proizvode od biomase. Biogoriva predstavljaju jedan od strateški najvažnijih održivih izvora energije te se smatraju važnom stavkom u napretku ograničavanja emisija stakleničkih plinova, poboljšanja kakvoće zraka i pronalaska novih izvora energije (Nigam i Singh, 2011.).



Slika 2 Nadzemni dio kulture *Sida hermaphrodita*
(<http://www.consulting-service-pflanzen.de>)

Sukladno Strategiji Europske unije za biogoriva (*EU Strategy for biofuels*, 2006.), biomasa se definira kao biorazgradivi dio proizvoda, ostataka i otpada iz poljoprivrede (uključujući biljne i životinjske tvari), šumarstva i srodnih industrija, te kao biorazgradivi dio industrijskog i komunalnog otpada. Biomasa predstavlja pohranjenu energiju koja se može crpiti po potrebi. Takve sirovine imaju tri glavne primjene: (i) stvaranje topline i/ili električne energije, (ii) gorivo za transport, i (iii) kemijska sirovina (McKendry, 2002.). Biomasa, kao i njezini produkti, nije samo obnovljiva, nego i dovoljno slična krutim i, nakon prerade, tekućim fosilnim gorivima, te je moguća njihova izravna zamjena (Krička i sur., 2007.). Trenutno biomasa predstavlja četvrti najveći izvor energije, odmah nakon nafte, plina i ugljena, te se iz nje proizvodi oko 14% ukupne potrebe za energijom godišnje s tendencijom rasta u razvijenim zemljama (Garcia i sur., 2012.). Uzimajući u obzir da je Republika Hrvatska zemlja s izrazito velikim potencijalom biomase za proizvodnju energije (oko 4 milijuna tona godišnje, trenutačno dostupnih) ona bi mogla zamijeniti do 25% ukupno utrošene energije (Krička i sur., 2007.). Poljoprivrednu biomasu za proizvodnju biogoriva druge generacije možemo podijeliti na: biomasu ratarske proizvodnje (sijeno, slama, stabljike, kukuruzovina, oklasak, ljuške ratarskih kultura), biomasu voćarsko

vinogradarske proizvodnje (orezani ostatci trajnih nasada), biomasu iz prerade i dorade poljoprivrednih sirovina u prehrambenoj industriji (komina grožđa, komina masline, komina uljarica, koštice voća, ljuske jezgričavog voća), biomasu iz povrćarstva i ukrasne hortikulture (otpad iz vrtova i parkova), biomasu stočarske proizvodnje (gnoj, gnojnica, klaonički otpad, mesno – koštano brašno), biomasu kultura za proizvodnju energije na zasebno oformljenim nasadima (*Miscantus sp.*, *Arundo donax*, *Sudannian grass*, *Reed canary grass*). (Bilandžija, 2014.)

Kulture za proizvodnju energije (brzorastuće energetske kulture) su one koje se uzgajaju isključivo u svrhu proizvodnje biomase. Cilj uzgoja energetskih kultura je proizvodnja, što je moguće veće, količine biomase po jedinici površine s ciljem njene pretvorbe u energiju. Energetske kulture mogu biti jednogodišnje ili višegodišnje biljke (Đonlagić, 2005.). Za razliku od jednogodišnjih, višegodišnje energetske kulture nemaju veće zahtjeve tijekom uzgoja i to prvenstveno u smislu agrotehnike i kvalitete poljoprivrednog tla. Jedna od takvih višegodišnjih kultura je vrsta *Sida hermaphrodita* (slika 2).

OPĆENITO O KULTURI *SIDA HERMAPHRODITA*

Sida hermaphrodita u engleskom govornom području poznatija je kao „*Virginia fanpetals*“ ili „*Virginia mallow*“ te se po samom imenu, usporedno s geografskim položajem savezne države Virginije prirodno joj je stanište jugoistočna obala kontinenta Sjeverne Amerike, dok druga riječ u imenu (*mallow*) ukazuje da se radi o biljci iz porodice sljezova (*Malvaceae*). *Sida hermaphrodita* kroz povijest nije bila kultivirana na prostoru SAD-a i Kanade, nego se tek ponegdje nalazila na očuvanim, močvarnim staništima te tlima s dovoljno vlage (COSEWIC, 2010.).

Energetski potencijal kulture *Sida hermaphrodita* prepoznat je već u drugoj polovici dvadesetog stoljeća na prostoru Poljske koja uvozi ovu kulturu te podiže prve intenzivnije nasade u Europi (Chudzik i sur., 2010). U Njemačkoj se trenutno uzgaja oko 750 hektara ove kulture na manjim parcelama diljem države (Franzaring i sur., 2013.).

Sida hermaphrodita, visinom u punoj zrelosti varira od jednog do četiri metra, ali najčešće postiže visinu od približno tri metra. Navedeno svojstvo biljci pruža mogućnost efektivne samoobrane od korova te joj oni u zreloj fazi ne čine problem, međutim, potrebno je obratiti pozornost na prisutnost korova te primijeniti metode suzbijanja istih u prvoj i eventualno drugoj godini uzgoja (Borowska i Molas, 2012.).

Mladice izbijaju iz tla krajem travnja i početkom svibnja iz krajeva brojnih bočnih rizoma prošlogodišnje biljke. Takvim nicanjem nastaje klonalna populacija nekog područja zbog boljih uvjeta za rast, naspram klijajućih mladica koje prije svega imaju potrebu razviti korijen u tlu koje je prekriveno vegetacijom. Kod vegetacijski razmnožavanih jedinki to nije toliki problem (Franzaring i sur., 2013.).

Uz navedenu prosječnu visinu od tri metra, debljina stabljike doseže prosječno tri centimetra. Listovi su duboko prorezani, nazubljeni i svojom građom podsjećaju na javorov list. Takvi jednostavno građeni listovi načinjeni su od 3-7 prorezanih dijelova. Cvatnja je karakteristična za razdoblje od kolovoza do listopada, a ponekad i duže, obično do pojave prvog mraza a formira cvat od mnogo bijelih cvjetova. Životni vijek ove kulture traje otprilike 25 godina (Kasprzyk i sur., 2013.).

SADNJA I ŽETVA

Sida hermaphrodita nema visoke zahtjeve što se tiče tla pa se tako za visoki i stabilni komercijalni prinos (od druge godine uzgoja) može uspostaviti na tlima klase IV (glejna tla A-G profila) ili V (tresetna tla T-G profila). Optimalna pH reakcija tla je neutralna, iako je blago kisela prihvatljiva, ali ne i poželjna (Borowska i Wardzinska., 2003.).

Vrijeme sadnje istraživane kulture je od 2. do 5. mjeseca, ovisno o lokaciji uzgoja. Kao sadni materijal se može koristiti sjeme, dijelovi krojenja te male presadnice kulture. Ovisno o biotskim i abiotskim faktorima, klijavost sjemena nije visoka (20-40%), te se stoga vegetativno razmnožavanje korijenom učestalo koristi u reprodukciji ove kulture. (Borowska i Wardzinska., 2003.). Preporučena norma sjetve iznosi 1 kg/ha, a sjeme se sije na razmak od 0,62 x 0,075m (Kasprzyk i sur., 2013.). Prosječan prinos iznosi približno 15 t ST/ha, iako uz pravilno oplodenu generaciju sa kvalitetnim uzgojnim mjerama ta količina može doseći čak 20 do 25 t ST/ha (Borowska i Wardzinska., 2003.). Ako se sadi u normi od 10 000 sadnica po hektaru, očekivani prinos na teškim tlima je 7,4 tone u prvoj i 10,3 tone u trećoj uzgojnoj godini. Ista norma na srednje teškim tlima daje prinos od 6,4 tone u prvoj godini i 11,4 tone u trećoj godini uzgoja. Svakako je bolja varijanta norme sadnje od 20 000 sadnica po hektaru gdje je očekivani prinos u prvoj godini 14,8 na teškim i 11,2 tone na laganim tlima, ali u drugoj godini čak 20,8 tona na teškim i 20,5 tona na laganim tlima (<http://vattenfall.pl>). Sjetvu/sadnju treba obaviti kada je tlo zagrijano na 7-8 °C. Kako je *Sida hermaphrodita* višegodišnja biljka sa slabim porastom u prvoj godini starosti, tijekom sljedeće dvije godine prinos je zagarantiran kao rastući, ali je potrebno svakih nekoliko godina provesti gnojidbu (Borowska i Wardzinska., 2003.).

Žetvu bi trebalo provesti u zimskom periodu godine zbog niskog sadržaja vlage (15-25%) u zelenoj masi, čime se smanjuju ekonomska izdavanja za sušenje biomase. Najbolje ju se provesti kada je tlo smrznuto ili snježni pokrivač vrlo tanak kako bi se mehanizacija mogla učinkovito koristiti. Za žetvu se najčešće koristi mehanizaciju za žetvu silažnog kukuruza (Borowska i Wardzinska., 2003.).



Slika 3 Usjev kulture *Sida hermaphrodita* u punom prinosu (<http://biomalwa.com>)

MOGUĆNOSTI ISKORIŠTENJA

Energetske mogućnosti iskorištenja

Ogrjevna vrijednost, kao temeljni energetski parametar, kulture *Sida hermaphrodita* prosječno iznosi oko 18 MJ/kg. Usporedno s hrastovim drvetom, oslobađa praktički jednaku količinu energije kao i hrastovina (Borowska i sur., 2003.). Nadalje, Borowska i Molas (2010) su ustvrdili kako prosječna količina proizvedene energije s jednog hektara biomase *Sida hermaphrodita* u kultivacijskom razdoblju između četvrte i šeste godine iznosi 366,55 GJ/ha godišnje. Kasprzyk i suradnici (2013.) su tijekom trogodišnjeg ispitivanja došli do zaključka kako jedan hektar vrste *Sida hermaphrodita* sadrži više suhe tvari, manje vlage te čak 20% veću energetsku vrijednost u odnosu na *Salix viminalis* (brzorastuća vrba). Jedan hektar kulture *Sida hermaphrodita* sadrži kapacitet za zamjenu 12 tona kamenog ugljena bez onečišćenja sumporom i klorom (Kasprzyk i sur., 2013.).

Kao i u slučaju različitih tipova biomase, dorade vrste *Sida hermaphrodita* za proces izravnog sagorijevanja se obavlja pomoću strojeva za proizvodnju peleta ili briketa. U tablici 1. su prikazane prosječne vrijednosti fizikalno kemijskih svojstva peleta i briketa biomase *Sida hermaphrodita*

Tablica 1 Fizikalna i kemijska svojstva peleta i briketa biomase *Sida hermaphrodita* (<http://biotek.pl>)

Komponenta	Mjerna jedinica	Standard kvalitete briketa i peleta				Prosječne vrijednosti peleta i briketa biomase Sida hermaphrodita
		Önorm, M 7135 (Austrija)		Standard DIN 51731 (Njemačka)		
		min	max	min	max	
Gustoća	kg/dm ³	1	-	1	1,4	1,9
Vlaga	%	-	12	-	12	9,7
Pepeo	%	-	0,5	-	1,5	2
Energija	kJ/kg	18	-	17,50	19,5	17,850
Sumpor	%	-	0,04	-	0,08	0,02
Klor	%	-	0,02	-	0,03	0,01
Dušik	%	-	0,3	-	0,3	0,13
Arsen	mg/kg	-	-	-	0,8	0,21
Kadmij	mg/kg	-	-	-	0,5	0,37
Krom	mg/kg	-	-	-	8	0,12
Bakar	mg/kg	-	-	-	5	3,47
Živa	mg/kg	-	-	-	0,05	0,03
Olovo	mg/kg	-	-	-	10	0,64
Cink	mg/kg	-	-	-	100	7,23

Na osnovi podataka iz tablice 1. može se uočiti da su skoro svi prikazani parametri u skladu s Önorm i DIN standardom za peletiranu i briketiranu biomasu. Određena odstupanja se mogu vidjeti samo kod gustoće biomase i udjela pepela u kulturi *Sida hermaphrodita*.

Ne-energetske mogućnosti iskorištenja

Obzirom na ne-energetske mogućnosti iskorištenja istraživana kultura se može koristiti za fitoakumulaciju na kemijski degradiranim terenima te deponijima smeća i otpada. Slijedom navedenog, *Sida hermaphrodita* ima sposobnost apsorpcije većih količina teških metala iz tla te time u bitnim količinama vrši biološku obnovu tla (Spooner i sur., 1985.).

Kako je cvatnja kulture *Sida hermaphrodita* najizraženija u periodu od početka kolovoza do pojave prvog mraza, a biljka cvate obilnim cvatovima, kultura je također poželjna u pčelarstvu odnosno proizvodnji meda. Med vrste *Sida hermaphrodita* sadrži tvari koje su poželjne u farmaceutskoj industriji (Kasprzyk i sur., 2014.). Mladice ove kulture imaju visok sadržaj proteina, vitamina C, karotena, kalcija i fosfora te kao takvi mogu služiti za hranidbu domaćih životinja. Zahvaljujući svome sastavu, proizvodi ove kulture nalaze plasman i na farmaceutskom području. Zbog visokog sadržaja celuloze, smole i voska u stabljici, također je potencijalno važna kultura za proizvodnju celuloze, a samim time i papira (Borowska i sur., 2003.).

UVODENJE VRSTE *SIDA HERMAPHRODITA* U HRVATSKU

U suradnji s OPG-om „EKO-Sever“ Agronomski fakultet u Zagrebu je 2014. započeo s istraživanjem kulture *Sida hermaphrodita*. U proljeće 2014. na površinama OPG-a „EKO-Sever“ posađena je kultura *Sida hermaphrodita* na površini od 10 hektara. Kao sadni materijal korištene su male presadnice, sađene na razmak 75x100 cm (12 000 biljaka/ha).

ZAKLJUČAK

Sve veće potrebe za energijom, težnja Europske unije za energetsom neovisnošću kao i mjere ublažavanja klimatskih promjena definiraju obnovljive izvore energije kao jedan od značajnih čimbenika za rješavanje dijela navedenih problema. Biomasa kao sastavni dio obnovljivih izvora energije, trenutno je najvažniji izvor sirovine za proizvodnju „zelene“ energije. Pod poljoprivrednom biomasom valorizira se i biomasa proizašla uzgojem višegodišnjih kultura za proizvodnju energije. Analizirajući vrstu *Sida hermaphrodita* kao energetska kulturu možemo zaključiti sljedeće:

- Moguća je žetva biomase s niskim udjelom vlage što smanjuje vrijeme i troškove daljnje dorade i proizvodnje,
- Svojom visinom rasta od 3 do 5 metara ova kultura nudi značajan prinos zelene mase po jedinici površine (do 25 t ST/ha),
- Jednostavna sjetva/sadnja i žetva s visokim stabilnim prinosom,
- Energetska vrijednost iznosi približno 18 MJ/kg,

- Medonosna biljka s više cvatnji godišnje,
- Kvalitetna biljka za fitoakumulaciju degradiranih tala,
- Jednostavno skladištenje i dorada,
- Niski zahtjevi biljke te niska početna ulaganja.

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SIDA HERMAPHRODITA AS ENERGY CROP

SUMMARY

Renewable energy resources represent energy resources that are used for production of electric and/or thermal energy. The reserves of mentioned resources constantly or cyclically renew themselves. Biomass that is cultivated for energy production is also classified as a renewable energy source. The purpose of planting quick growing crops is high yield production with the aim of crop transformation into energy. Energy crops include annual and perennial plants. As opposed to annuals, perennial energy crops are less demanding during cultivation in terms of agricultural machinery and soil quality. The possibility of cultivation on lower quality soils is of utmost importance in avoiding collision between energy and food production. Sida hermaphrodita is an example of such perennial crop. Basic characteristics of this crop are: high yield of dry matter (10 – 25 t/ha), high energy value (18 MJ/kg), a favourable lignocellulose composition and minimal requirements and low initial investment during

cultivation. In 2014, in cooperation with „EKO-Sever“ family farm, the Faculty of Agriculture in Zagreb began research on Sida hermaphrodita crop.

Key words: *renewable energy resources, energy producing crops, biomass, Sida hermaphrodita*



INVESTIGATION ON POSSIBILITIES OF BIOMETHANE PRODUCTION FROM CORN STOVER IN VOJVODINA

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SUMMARY

Corn is the most widely grown field crop, seeded on almost one third of the available arable land in Serbia and recently on about one half of the arable land in agricultural region Vojvodina. Therefore, corn stover, i.e. corn harvesting residue, known as maize straw as well, has significant potential for energy generation in Vojvodina. Within this study, possibilities to use corn stover as substrate for biomethane production in Autonomous Province of Vojvodina have been investigated. Therefore, investigation is performed to determine substrate related properties of corn stover and available amount that could be utilized for production of biomethane. For determination of potential biomethane yields, which is the most important property, the batch digestion approach has been applied. Samples of corn stover from the five, in Vojvodina, dominate corn hybrids are used. The obtained results are: 1) organic dry matter content 94.9-96.7 % (d.b.); 2) potential biogas yield 390.3-549.0 Nm³/t_{ODM} of used corn stover; 3) methane content in produced biogas 47.4-54.9 %. The theoretical potential is significant, which expressed in power output of biomethane primary energy could reach approximately 900 MW_p. Furthermore, technical potential for biomethane production in Vojvodina, considering three different scenarios with 30, 50 and 70 % of totally produced biomethane in co-digestion with manure, could be 26, 53 and 118 MW_p, respectively. Therewith, obligatory goal for use of advanced biofuels in Serbia could be attained. Tasks for further research are to find out solutions to overcome hindrances for utilization of corn stover as substrate for biogas production, e.g. low digestibility and therewith long retention time, which would enable achievement of determined technical potential.

retention time, which would enable achievement of determined technical potential.

Key words: corn stover, properties, substrate, potential, biogas, Vojvodina

INTRODUCTION

RES policy in EU and Serbia

According to *Directive 2009/28/EC* (Anonymous, 2009a), the share of biofuels for transportation has been defined to be at least 10 % up to 2020. Recently, the focus is on production and use of advanced biofuels produced from non food / non feed renewable resources. In line with this, in September 2013 in EU parliament it was adopted that “first generation” biofuels should not exceed 6 %, as opposed to the previously 10 % target in the legislation, while advanced biofuels should represent at least 2.5 % of fuel consumption in transport (Anonymous, 2014). Double-counting of biofuels produced from utilized cooking oil or animal wastes, was endorsed as well.

Every EU member country is obliged to achieve these goals, but candidate countries, like Serbia, as well, which signed a *Memorandum of integration into the EU energy market* (Anonymous, 2007), and therewith pledged to follow EU policy in this field. In Serbia, the goal for RES utilization was clearly stated by the *National action plan* (Anonymous, 2013a) and obligation to adopt the incentive measures by *Energy Law* (Anonymous, 2012a).

Corn stover as substrate for biomethane production

According to Serbian RES National Action Plan (Anonymous, 2013a), biomass is recognized as the largest RES potential in Serbia with share of 64%. Crop residues, *i.e.* agricultural residual biomass, represent significant potential, particularly in agricultural region Vojvodina. Corn is the most widely grown field crop, seeded on almost one third of the available arable land in Serbia and recently on about one half of the arable land in agricultural region Vojvodina. Therefore, corn stover, *i.e.* corn harvesting residue, known as maize straw as well, has significant potential for energy generation in Vojvodina, either for co-generation, generation of heat or production of biofuels for transport.

Corn stover has mostly high moisture content, what is considered as significant drawback when using it for *e.g.* combustion. More appropriately, corn stover could be utilized in the process of anaerobic digestion, *i.e.* for production of biogas. Produced biogas could be upgraded and biomethane obtained, *i.e.* purified to quality of natural gas by removing CO₂ and impurities like H₂S. Biomethane, if produced from corn stover in co-digestion with manure or other organic waste, could be considered as an advanced biofuel and utilized in transport. It is supposed that biomethane produced from corn stover in co-digestion with manure could satisfy sustainability criteria set out in the *Directive 2009/28/EC*, Article 17, Paragraph 2, wherewith it is defined that greenhouse gas emission saving of biofuels use from 2018 on shall be at least 60 %. The environmental impact of biomethane production from corn stover is up-to-date topic and is being investigated by numerous research groups.

Previous research on biogas production from corn stover

When considering organic material as substrate for biogas production, the most important property is potential biogas yield, i.e. a potential for energy generation. Mostly, potential for energy generation is expressed with respect to DM or more properly to ODM, since moisture and inorganic matter could not be digested and therefore represent ballast. Therefore, DM or ODM represent relevant properties. Methane content determines more precisely the potential for energy generation, since other compounds in biogas are not combustible, whereof the carbon-dioxide has the largest share. In Table 1 are summarized results from previous research with respect to properties of corn stover as substrate for biogas production.

Table 1 Properties of corn stover as substrate for biogas production

Biogas yield, Nm ³ /t _{DM}	Biogas yield, Nm ³ /t _{ODM}	Methane content, % (v/v)	DM content, %	ODM content, %	Reference
na	325	54.9	94.72	91.20 ²	Zhong et al. (2012)
na	na	na	95.20	94.30 ²	Hu and Yu (2005)
260	na	48.0	93.99	87.44	Zhong et al. (2011)
na	304 ¹	56.0 – 60.0	92.20	87.50	Xu and Li (2012)
na	na	na	91.80	88.10	Shi et al. (2013)
na	238 ¹	na	92.20	87.50	Xu et al. (2013)
na	450	55.0 – 60.0	92.45	85.24	Zhou et al. (2012)
na	335	64.9	30.77	89.05 ²	Chen et al. (2010)
na	260 ¹	55.4	88.80	83.60	Li et al. (2013)

Remarks: ¹⁾ related to methane yield; ²⁾ share of ODM in DM; Nm³: normalized cubic meter; DM: dry matter; ODM: organic dry matter; na: not available.

Objectives

The first objective was to investigate possibilities of biomethane production from corn stover, considering its relevant properties as a substrate for biogas production. Further objective was to determine potential of corn stover as substrate for biogas production in Vojvodina.

MATERIALS AND METHODS*Corn stover samples*

Samples of the five corn hybrids were used and experimentally analyzed: *Pako*, *Luce*, *Korimbos*, *NS 6010* and *Grecale*. These are wider used hybrids in Vojvodina, divided into FAO groups, Table 2.

Table 2 Selected hybrids and their FAO groups

Name of the hybrid	FAO group
Pako	490
Luce	550
Korimbos	600
NS 6010	600
Grecale	700

Inoculum

Inoculum, used to initiate process of anaerobic digestion within experimental reactors, was collected as digested residue from the agricultural biogas plant in the vicinity of Novi Sad. As the input materials in this biogas plant are used liquid and solid manure in co-digestion with corn silage and recirculated digested residue. The mass ratios of these co-substrates within admixture were 59 %, 18 %, 13 %, 10 %, respectively.

Determination of corn stover properties

Determination of dry matter (DM) and organic dry matter (ODM) of the corn stover samples and inoculum was performed in accordance to standard procedures (Anonymous, 2012b; 2012c), using drying oven, muffle type oven and balance. The batch anaerobic digestion procedure was conducted to determine the potential biogas yield (Anonymous, 2006). As reactors and collection system for the produced biogas, 1 L glass bottles linked to the 2 L plastic gas bags by the PVC hoses and quick release couplings were used. Biogas production was measured with a drum-type volumetric flow meter (Ritter TG1/1).

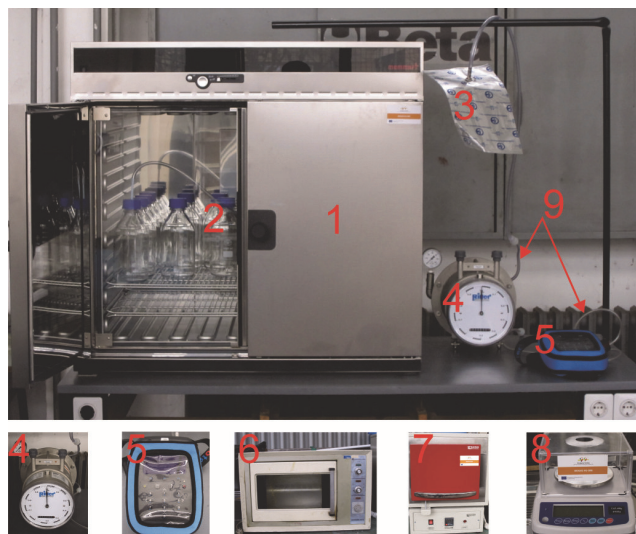


Figure 1 Setting up of experiment for determination of corn stover properties; 1) Climate chamber; 2) glass bottles (reactors); 3) gas bags; 4) drum-type volumetric flow meter; 5) gas analyzer; 6) drying oven; 7) muffle type oven; 8) balance

The vacuum pump (KNF-NMP 830 KNE) was used to drive collected biogas through the flow meter in another gas bag from which it was sampled and gas composition determined by gas analyzer (Geotech BIOGAS 5000). The initial ODM content of the analyzed substrates in the reactors was 5.25 g_{ODM} and the substrate to inoculum ODM ratio was 0.5. The working volume of the reactors was 0.7 L. The reactors were incubated in the climate chamber (MEMMERT IFE 600 D7) for thirty days under mesophilic conditions (37±2 °C). Each reactor was manually stirred on daily basis for several minutes. For each hybrid, three reactors were used. The experiment setting up for determination of corn stover properties is presented in Figure 1.

Since there were five populations of obtained results for biogas yield, *i.e.* biogas yield was determined for five samples of corn stover from five corn hybrids, single factor ANOVA was used. Therewith, it was analyzed if there are significant differences between the results, *i.e.* if choice of hybrid has influence on biogas yield. Three samples of the hybrids were also used for determination of DM and ODM. For each group of obtained experimental data, statistical data processing was carried out using single factor ANOVA ($\alpha = 0.05$) and Student's t-test.

Determination of potential for biomethane production

Determined potential for biomethane production in Vojvodina will be given by the quantity of corn stover to be used as substrate, annual biomethane production and power output of primary energy. First, theoretical potential will be determined based on totally available corn stover when common harvesting technologies are applied. For this, data regarding sowing structure and corn grain provided by Statistical Office of the Republic of Serbia (Anonymous, 2013b). Then, by considering preservation of soil fertility due to nutrient removal and protection of erosion as well as data regarding harvestable amounts of corn stover applying in Golub *et al.* (2012) and Martinov *et al.* (2014), technical potential in three scenarios will be determined. Corn stover quantities would be available to use it in co-digestion with manure, to substitute energy crops that have high price. In the three scenarios corn stover will make 30, 50 and 70 % of totally produced biomethane. Quantities of manure are taken over from Tesic *et al.* (2013). To determine the theoretical and the technical potential, following data and facts are used. Organic dry matter content and potential methane yield from corn stover is used as mean value of the determined values of the five corn hybrids in the conducted experiment from this study. Net heating value of methane is 9.97 kWh/Nm³. To determine power output of biomethane primary energy, it is considered that facility is 8,760 h in operation.

RESULTS AND DISCUSSION

Properties of corn stover

Determined DM and ODM contents are presented in Table 3. Biogas and methane yield are subsequently specified in relation to the determined DM and ODM. By comparing with results from previous research (Table 1), all five hybrids have, to some extent, lower DM content. The highest value has hybrid Pako, 91.1 %. In opposite, values of ODM content, which rate approximately between 85 % and 88 %, are similar to those presented in Table 1.

Table 3 Determined DM and ODM content of the five analyzed corn hybrids

Hybrid	DM content		ODM content		ODM content (<i>d.b.</i>)	
	%	SD	%	SD	%	SD
Pako	91.1	0.003	88.2	0.003	96.7	0.004
Luce	90.6	0.002	86.7	0.004	95.6	0.003
Korimbos	90.9	0.006	87.7	0.006	96.4	0.006
NS 6010	89.4	0.017	84.9	0.019	94.9	0.020
Grecale	89.4	0.021	85.7	0.023	95.9	0.005

SD: standard deviation

Biogas yield and methane content, which are the most important properties to determine potential for biomethane production, are presented in Table 4. The highest biogas yield has the hybrid *Korimbos* 529.8 Nm³/t_{DM}, as well as the largest methane content 54.9 %. Next two are *NS 6010*, *Pako* and *Luce*. The lowest biogas yield has the hybrid *Grecale*, 374.6 Nm³/t_{DM} and methane content 53.5 %.

Table 4 Biogas yield and related methane content

Hybrid	Biogas yield		Biogas yield		Methane content	
	Nm ³ /t _{DM}	SD	Nm ³ /t _{ODM}	SD	% (v/v)	SD
Pako	440.6	0.990	454.9	1.02	47.4	0.23
Luce	421.2	5.739	439.6	5.99	53.9	0.72
Korimbos	529.8	34.746	549.0	36.00	54.9	0.43
NS 6010	516.3	18.904	544.8	19.87	53.9	0.38
Grecale	374.6	81.051	390.3	84.45	53.5	1.20

SD: standard deviation

In comparison with results from previous studies (Table 1), which are diverse, the investigated hybrids have mostly higher biogas yields, and approximately similar values of methane content. For example, Zhong *et al.* (2011), who has only specified biogas yield related to DM content that is only 260 Nm³/t_{DM}, is considerably lower even than the lowest biogas yield in this study, *i.e.* 374.59 Nm³/t_{DM} for *Grecale*. Results reported in Zhou *et al.* (2012) with value 450 Nm³/t_{ODM} are comparable with here obtained biogas yields. The sole higher value of biogas yield than here obtained is reported by Xu and Li (2012), 506.7–542.8 Nm³/t_{ODM}, although the stated value is for methane yield. In comparison with theoretical biogas and methane yields of other substrates, corn stover has lower yields, which is typical for other ligno-cellulosic substrates as well.

Results of analysis are presented in Table 5. Since $F > F_{crit}$, it was concluded, with $\alpha=0.05$, that there are significant differences between the results. By using Student's t-test, it was concluded between which of them are differences significant (Table 6). In general,

hybrid *Grecale* had significant differences comparing to other hybrids, and also difference was identified between hybrids *Korimbos–NS 6010*.

Table 5 The result of applied ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	248,560.9754	5	49,712.19508	12.2933605	0.000336512	3.203874261
Within Groups	44,482.07192	11	4,043.82472	–	–	–
Total	293,043.0473	16	–	–	–	–

SS: sum of mean square; df: degree of freedom; MS: mean square.

Table 6 The results of applied Student's t-test

Compared hybrids	P (T<=t) one - tail	P (T<=t) two - tail
Pako–Luce	0.034	0.068
Pako–Korimbos	0.022	0.045
Pako–NS 6010	0.008	0.016
Pako–Grecale	0.158	0.316
Luce–Korimbos	0.017	0.035
Luce–NS 6010	0.001	0.003
Luce–Grecale	0.209	0.419
Korimbos–NS 6010	0.405	0.811
Korimbos–Grecale	0.028	0.057
NS 6010–Grecale	0.046	0.093

Biomethane potential in Vojvodina

In Table 7 are presented potentials of corn stover that could be used as substrates for biomethane production. The most important figures are the total annual production of corn stover and yields with respect to acreage. For the seasons 2010-2013, the average values are $3.5 \cdot 10^6$ t/a and 4.9 t/ha, respectively. This is further in Table 8 used as theoretical potential of corn stover in Vojvodina.

The presented theoretical potential for biomethane production is large and expressed in the power of biomethane primary energy reaches nearly 900 MW_p. However, this potential could not be reached in practice due to complex biomass logistics and losses. Furthermore, it is likely that corn stover would be used in co-digestion with manure on larger livestock farms, which is given by the three scenarios. In the first scenario, where biomethane production from corn stover rates 30 % with respect to manure, only lower share of energy crops at potential biogas plants in Vojvodina could be substituted. In the second scenario, it could be considered that total amount of energy crops at potential biogas plants could be substituted and in the third scenario even the higher share of the produced biomethane could come from corn stover. These findings are based on assumption that potential biogas

plants, will commonly use manure in lower share and energy crops, agricultural by-products or other organic waste in higher share as substrates for biogas production.

Table 7 Corn stover potentials for biomethane production in Vojvodina

Season	Grain		Corn stover				
	Harvested acreage, 1,000 ha	Total production, 10 ⁶ t/a	Yield, t/ha	Harvest index	Total production of above ground biomass, 10 ⁶ t/a	Total production, 10 ⁶ t/a	Specific yield, t/ha
2010.	699	4.0	5.8	0.50	8.0	4.0	5.8
2011.	733	3.8	5.1	0.51	7.4	3.6	4.9
2012.	752	1.9	2.6	0.41	4.8	2.8	3.7
2013.	684	4.3	6.3	0.44	8.1	3.7	5.4

According to Serbian RES National Action Plan (Anonymous, 2013a), 267 ktOE of biofuels should be produced and utilized in transport, whereof approximately 67 ktOE of advanced biofuels. Therefore, in the first and in the second scenario, biomethane production would significantly contribute to production of advanced biofuels, 30 and 60 %, respectively. In the third scenario entire quantity of advanced biofuels that should be produced in Serbia could be provided solely from corn stover as substrate in Vojvodina, in the form of biomethane.

Table 8 Potentials of biomethane production in Vojvodina

	Corn stover, 1,000 t/a	Annual biomethane production, 10 ⁶ m ³ /a	Power output of biomethane primary energy, MW _p	Replacement of biofuels, ktOE
Theoretical potential	3,550	773	880	660
1 st scenario	105	23	26	20
2 nd scenario	214	47	53	40
3 rd scenario	476	104	118	90

CONCLUSIONS

The possibilities of biomethane production from corn stover in Autonomous Province of Vojvodina have been investigated. For this purpose, relevant properties as a substrate for biogas production and potentials in Vojvodina are determined and discussed. By analyzing substrate related properties, DM and ODM content of the investigated samples biogas were determined and make approximately between 89 and 91 %, and 85 and 88 %, respectively. However, these values are obtained for samples stored in the laboratory and could be significantly lower after harvest, depending on weather conditions. When determining methane yield of corn stover from five different hybrids of corn, characterized by different

FAO groups, it was found that hybrid *Korimbos* has the highest biogas yield 529.8 Nm³/t_{DM}, with methane content of 54.9 %. These values are comparable with the highest ones determined within previous research, but comparing with yields of other substrates these are significantly lower.

Considering potential of corn stover for biomethane production in Autonomous Province of Vojvodina, it could be concluded that it is significant. The theoretical potential expressed in power output of biomethane primary energy reaches approximately 900 MW_p, for what the entire amount of corn stover in Vojvodina should be collected and used. Considering corn stover as co-substrate with manure, the technical potential of biomethane from corn stover is determined and would rate between 26 and 118 MW_p. By solely use of the technical potential of biomethane generated from corn stover and in Vojvodina, the goal for use of advanced biofuels in Serbia, till 2020, could be achieved.

For further research, logistic aspects related to harvest, transport and storage of corn stover as substrate for biogas production should be investigated. Particular problem considering properties as substrate for biogas production represents low digestibility of corn stover, causing low biomethane yields and long retention time in the digester. Therefore finding out an appropriate pre-treatment of corn stover is research objective of the great importance, which is investigated at many R&D institutions.

ACKNOWLEDGEMENT

This work was funded by the Provincial Secretariat for Science and Technological Development of Autonomous Province of Vojvodina (project no.: 114-451-1139).

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ENERGY CONSUMPTION TO THE FORMATION OF SOLID – LIQUID SYSTEMS BASED ON VEGETAL BIOMASS

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ABSTRACT

In the latter 20th century, anaerobic digestion gained popularity as a solution to environmental and energy concerns. In the present paper, two types of vegetable residue (corn stover and mountain grass) have been grinded with the lab mill Grindomix GM200 for 1 min. At 5000rpm and granulometric devised in tree fractions with a sieve shaker model Vipo at 150 osc/min. Different quantities of this material have been used, at three different granulations, an dthree different concentrations in the mix with fresh water and mixed with a F126 mixer, B, CEK Armfield. In every case, the necessary power at mixing the upper materials. At four or five speed values was determined. These materials will be used as vegetable substrate for anaerobic fermentation and biogas production. Significant differences between the values of necessary mechanical power for mixing and electrical power determined with an ampermetric claw. The variation of both powers with revolution presented rising tendency, respectively with liquid mix concentration – solid, but the difference between the three biomass granulations could not be put in real evidence.

Determining the best solid-liquid concentration is wanted, which will present the best fermentation characteristics, respectively out of which the best production of biogas will be yielded. Results from this paper could be useful for specialists in the field of biomass processing in order to determine energetic efficiency of each presented scenario.

Key words: biomass, solid-liquid, mechanical power, electrical power, biogas

INTRODUCTION

Mixing is the homogenization operation of two or more substances with the purpose of obtaining a produce with the same composition in the entire volume (mechanical homogenization) or with the same temperature (thermal homogenization). Mixing is used in some technological processes for accelerating chemical reactions and some physical processes. It can be an independent operation when it is used for obtaining products that are mixes of two or more components or it can be auxiliary when it creates optimum conditions of t emain operation, intensifying heat transmission, at suspension separation, for substance extractions, chemical reactions or physical state change.

Mixing is done in two phases. The first phase is where a mix in vicinity of the device is realized or a piece that realizes the mix, forming small areas of mixture in which currents with different speeds take place and lead to moving the material and is called local mixing. In the second phase, material volumes in the mixture in the vicinity of mixing equipment move other material volumes in their vicinity.

In the case of anaerobic digestion fermenters, mixing is realized in the purpose of substrate homogenization and creating the necessary conditions for internal processes of discomposure and biogas transformation [2, 5, 8].

So, anaerobic digestion is a process in which microorganisms break a biodegradable material in the absence of oxygen. It can be used for decomposing organic waste and recuperating bio-energy as biogas, with an important methane content [2, 5, 8].

The anaerobic digestion process is characterized by a series of biochemical transformations brought on by different mixtures of bacteria. The rate of hydrolysis depends on the pH, temperature, composition and concentration of intermediate compounds. The technical and economical performance if an anaerobic digester depends on how much methane is yielded and the purity and on the wastewater characteristics, due to biomass chemical composition and process variables (temperature, retention time, pH) [3].

The performance of a digester is affected by the degree of contact between substrate and the bacterial population. This contact can be increased by mixing the substrate. Mixing is considered to be essential in anaerobic fermentors with a high volume, but the optimum mixing module is still a debate subject, [6].

Mixing can be realized in many ways: mechanical mixers, biogas recirculation and slurry recirculation. Out of these, mechanical mixers are considered the most efficient in terms of power consumption per volume mixed. Also, at small concentrations of manure slurry in the fermentation mix, the mixture does not present a visible effect on biogas production, but at 10-15% concentration, mixing becomes very important [6]. Within an anaerobic digester, agitation of the slurry substrate is necessary to ensure a uniform mixture of heat and bacteria. Through mixing, the substrate components are uniformly distributed in the mixture and prevents the formation of zones without substrate.

One of options for improving yields of anaerobic digestion of organic matter is co-digestion. Co-digestion is the simultaneous digestion of a homogenous mixture of two or more substrates. Through co-digestion, waste with poor fluid dynamics, floating waste or components with a high degree of disturbance or inhibition can be used more efficiently as cosubstrates when co-digest with well performing sewage sludge or liquid manure, [10].

In paper [1], are presented some investigations of the rheological behavior of fermentation substrates and the influence of the flow regime in stirred biogas plants. It is shown that even a small change of the viscosity has a substantial impact on the flow profile and therefore on the mixing time.

Among other disturbances that are caused by the mixing technique and need to be avoided are the creation of floating and sinking layers. Therefore, sinking layers lead to a reduction of the space available for the fermentation process and must be removed from time to time.

Evaluating of the efficiency of two different agitation systems was made by Lemmer et colab. [5], by measuring the nutrient distribution in a digester fed with renewable energy crops and animal manure. Have been set three different types of stirring and feeding procedures.

Samples were taken from a full-scale biogas digester in combination with the electric energy consumption for evaluation. It has been found that are differences in nutrient distribution depending on the investigated agitation system, as well as position and height of the sample in digester. The data show that all three agitator setups differ significantly in their electric energy consumption.

In their paper Pound B. et al. [9] investigated the influence of the percent of pressed sugar-cane stalk in mixture with cattle slurry on biogas production, in the presence or absence of urea. Authors concluded that if the vegetable mass percentage (sugar-cane stalk) in the fermentation mixture rises when biogas production can be seriously affected. Also, the addition of urea lead to a rise in pH and a decrease in fermenting time.

Our paper presents results of experimental research referring to biomass formulas mixing (different types) power necessity (mechanical and electrical) and water, in different concentrations, with a mechanical mixer (with two types of mixing organs - blade paddles and propeller), which can be used for anaerobic bioreactors for biogas yield. Also, the paper presents differences which can appear for mixing necessary power recording module (mechanical and electrical), for more mixing organ revolution values.

MATERIAL, METHODS AND PROCEDURES

In the mixing bowl of a CEK-A, made by Amfield, 18 liters of tap water and grinded vegetable biomass were added. The apparatus consists of a clear acrylic cylindrical mixing vessel over which is mounted a variable speed motor which drives a vertical drive shaft. An electronic controller is used to vary the speed of the drive shaft, and a tachometer gives an accurate indication of shaft speed. Speed range of drive shaft is 0-500 rpm.

A dynamometer, mounted on a bridge, measures the torque using a direct reading force balance. The torque is measured by a direct reading force balance dynamometer with a power range of 0-75 W.

Figure 1 presents the scheme of the Amfield CEK lab mixer

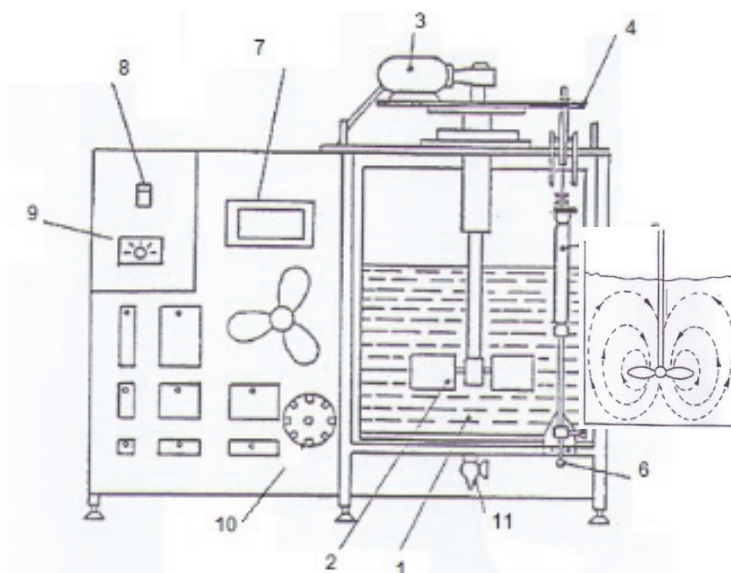


Fig.1 Armfield CEK Mixer; 1.vessel; 2.omogenizing paddles; 3.motor electric; 4.dynamometer arm; 5.balance; 6.balance adjustment; 7.speed indicator; 8.on/off switch; 9.speed controller; 10. instrument panel; 11.drain valve

In order to determine the necessary power for acting an ampermetric claw was used. Exttech mounted on the phase wire of the cable. Multiple solid-liquid mixes were tested, with different biomass concentrations in the mix, but also different grinded biomass granulations. For obtaining the necessary biomass in the experimental tests dried corn stems were used, with a 10.2-10.5% humidity and mountain grass, mowed manually, with a 11.5 – 11.6% humidity.

These materials were first grinded with an electrical grinder for vegetable residue Viking GE260 of 2,9 kW, and then finely grinded with a Grindomix GM-200 lab mill for 1 minute, at 5000 rpm. After grinding, the material was devised in three fractions, being screened for 1 minute, with a sieve classifier VAPO (Chech Republic) with sieves of 3.15mm and 2.5 mm. Thus, on the sieve a 3 -5 % material percentage out of the particles remained are grinded stalks with lengths no more that 3 cm (about 40% had this length or higher).

Out of the grinded material, corn stove and mountain grass, the test samples were prepared. For both types of biomass the solid material in the water calculated was 2.5 %, 5% and 10%.

For mixing blade paddles for homogenization were used with dimensions 40x60 mm and a propeller, both from CEK mixer. The action range of the blade paddles is about 60 mm and the action range of the propeller is about 45 mm. During tests, the shaft speed was modified at values: 100, 150, 200, 250 rpm. For some probes 300rpm speed was used. The force recorded by the dynamometer arm of the apparatus was read, as well as the electric current intensity indicated by the ampermetric claw. Grid tension, of 220V was determined.

Torsion moment for the drive shaft was calculated with the relation:

$$\text{Torque}(T) = \text{Force}(F) \times \text{Torque arm radius}(r) \quad (1)$$

The drive force is equal with the indication read on the apparatus dynamometer, in kg, times the gravitational acceleration g , in m/s^2 .

Necessary mechanical power for mixture homogenization in the mixture was calculated with the relation:

$$\text{Mechanical power}(P) = \text{Torque}(T) \times \text{Angular speed}(\omega) \quad (2)$$

Electric power was also calculated with the relation:

$$\text{Electrical power}(P) = \text{Tension}(U) \times \text{Current}(A) \quad (3)$$

Determining the necessary power for biomass mixing is necessary in all situations in which practice asks for it, but our paper followed the necessity for determining the energy consumption at biomass mixing in anaerobic fermentors, as a necessity for obtaining a higher biogas production. We haven't got to solid-liquid concentrations yet that present comparative values with the ones in real practice, but we assume this fact and in another paper we will present new facts.

The analysis method is common in these situations, revolutions used for determinations being in close connection with the necessity of obtaining homogeneous mixtures, so that in all its mass the homogeneous degree to be the same, and the agitation organ must be in this sense and not in the sense of obtaining with priority a low energy consumption without taking this aspect into consideration.

RESULTS AND DISCUSSION

Results obtained for experimental determinations with grinded biomass from corn stalks and mountain grass are presented in tables 1 and 2.

Based on the presented results in these tables variation of mechanical power and variation of electrical power with drive shaft have been graphically drawn. As it can be seen both from tables, as well as from the graphs presented, there is a very high difference between the values of mechanical and electrical power (10-20 times).

It is thus, very important choosing the material mixing necessary power determination module, indifferent of their physical state.

Although there is a rising tendency of the power variation with drive shaft speed, for the two types of biomass, respectively for different granulation of grinded material, these differences could not be put into a significant evidence.

Table 1 Results obtained during experiments for corn stalks, for grinded particles

Shaft speed, rpm	Balance indication, kg	Mechanical power, W	Current, A	Electrical power, W	Balance indication, kg	Mechanical power, W	Current, A	Electrical power, W
Blade paddles					Propeller			
2.5%								
100	0.139	1.57	0.21	46.93	0.130	1.47	0.18	40.33
150	0.144	2.45	0.29	64.53	0.132	2.23	0.24	53.53
200	0.152	3.43	0.39	86.53	0.133	3.01	0.30	66.00
250	0.160	4.52	0.48	106.33	0.135	3.80	0.34	74.80
5%								
100	0.137	1.55	0.19	41.80	0.130	1.47	0.19	41.80
150	0.142	2.40	0.27	60.13	0.131	2.23	0.25	55.00
200	0.149	3.38	0.39	85.80	0.133	3.00	0.30	66.00
250	0.158	4.46	0.49	107.80	0.134	3.78	0.35	76.27
10%								
100	0.136	1.54	0.19	41.80				
150	0.140	2.37	0.27	59.40				
200	0.148	3.34	0.36	79.20				
250	0.159	4.48	0.44	96.80				
300	0.178	6.02	0.51	112.20				

Analyzing the graphics presented in fig. 2, for mixing biomass out of grinded corn stalks, it could be concluded that there is a significant difference between the variation of mixing power consumed during mixing process with strate pallets and a propeller mixer, disregarding the measuring method (mechanical power, respectively, electric power), disregarding the concentration of the liquid-solid composition.

The mechanical power starts around the value of 1.5 W (for concentrations of 2.5% as well as for 5% and 10%), for a revolution of 100rpm, and grows towards 4.5W, for a revolution of 250 rpm, using blade paddles, meanwhile for the propeller homogenizer is 4 W for the same revolution of 250 rpm, the growing tendency being exponential. This tendency stands out better for revolutions of 200 rpm.

Regarding the electric power variation in correlation to agitation axle revolution, disregarding the homogenizator type, the growing tendency is predominant linear (for the revolutions area in which test were made), existing here also significant differences between the values obtained during mixing with blade paddles and the one obtained with a propeller homogenizer, but in this case the values start from 40 W, for a revolution of 100 rpm, reaching 106 -107 W for a revolution of 250 rpm (for 2.5% as well as for 5% solid

concentration in water), respectively 112 W, for a revolution of 300 rpm and a concentration of 10% if a blade paddles homogenizer is used.

For a propeller type mixer, the electric power increase up till values of about 75 - 96 W, for both concentrations of 2.5% and 5%.

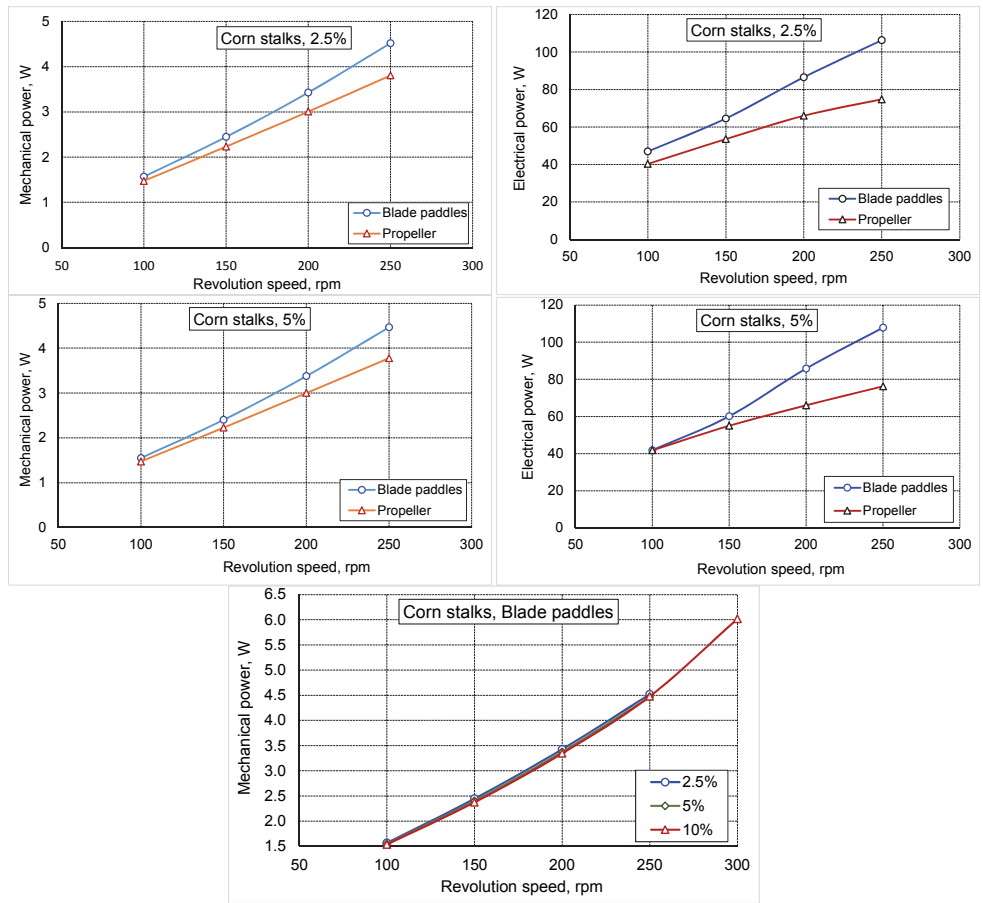


Fig. 2 Mechanical power variation, respectively electric power, in correlation to homogenizator revolution for grinded corn stalk mixing

Table 2 Results obtained during experimental tests with grinded mountain grass

Shaft speed, rpm	Balance indication, kg	Mechanical power, W	Current, A	Electrical power, W	Balance indication, kg	Mechanical power, W	Current, A	Electrical power, W
Blade paddles					Propeller			
2.5%								
100	0.135	1.53	0.17	37.4	0.13	0.55	0.15	33
150	0.14	2.37	0.24	52.8	0.131	0.78	0.19	41.8
200	0.146	3.30	0.33	72.6	0.131	1.07	0.24	52.8
250	0.155	4.38	0.42	92.4	0.131	1.37	0.28	61.6
300	0.159	5.39	0.49	107.8	0.132	1.61	0.32	70.4
5%								
100	0.137	1.55	0.17	37.4	0.13	1.47	0.15	33
150	0.141	2.39	0.24	52.8	0.131	2.22	0.19	41.8
200	0.15	3.39	0.34	74.8	0.131	2.96	0.23	50.6
250	0.16	4.52	0.44	96.8	0.132	3.73	0.28	61.6
300	0.168	5.70	0.5	110	0.132	4.47	0.32	70.4
10%								
100	0.135	1.53	0.17	37.4	0.13	1.47	0.15	33
150	0.14	2.37	0.23	50.6	0.13	2.20	0.19	41.8
200	0.148	3.34	0.32	70.4	0.131	2.96	0.23	50.6
250	0.155	4.38	0.42	92.4	0.131	3.70	0.26	57.2
300	0.175	5.93	0.49	107.8	0.131	4.44	0.29	63.8

For homogenization of grinded mountain grass mixing, in concentrations of 2.5%, 5% and 10% in water, the differences between concentrations couldn't be highlighted, no matter the homogenizator type, but also the way of the power read (mechanical or electric). Also here the variation tendency was an increasing one (as it can be seen in fig. 3), the mechanical power values increasing from around 1.5 W at 100 rpm, no matter if blade paddles or propeller are used, until about 5.4-5.9%, for 300 rpm revolution for a blade paddles homogenizator, having values smaller (about 4.5 W) for the propeller type homogenizator. Also, the electric power values had an increasing tendency (approximate linear) in the area 37 - 107 W, for a blade paddles homogenizator and between the limits 33-70 W for propeller type homogenizator, disregarding the solid concentration in water.

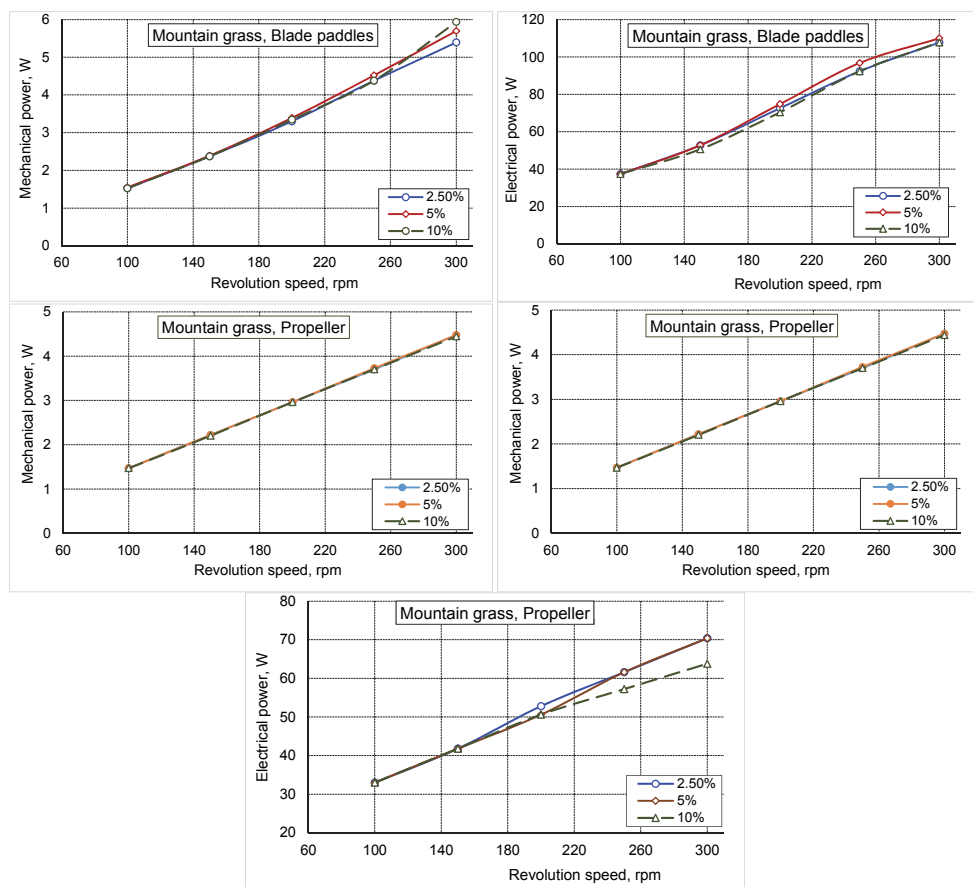


Fig. 3 Mechanical power variation, respectively electric power variation, in correlation with homogenizator revolution during grinded mountain grass mixing

Referring to fig.4. where the powers variation (mechanical, respectively electrical) is presented, in correlation to homogenizator type and revolution, it could be seen the differences between the power variation with homogenizator type, no matter the recording way of power, but also the solid concentration in water, the tendency being an increasing one, mainly exponential for revolutions of 200 rpm for mechanical power and approximative linear for electric power variation. The difference is better seen for higher revolutions of the mixing axel, for mechanical power as well as for electric power.

Regarding the necessary power during mixing of different types of grinded biomass, it could be obvious for electric power registration and it couldn't be obvious for mechanical power registration, for the solid - liquid concentration, used during our experimental tests, no matter the homogenizator revolution, especially while using the propeller type homogenizator.

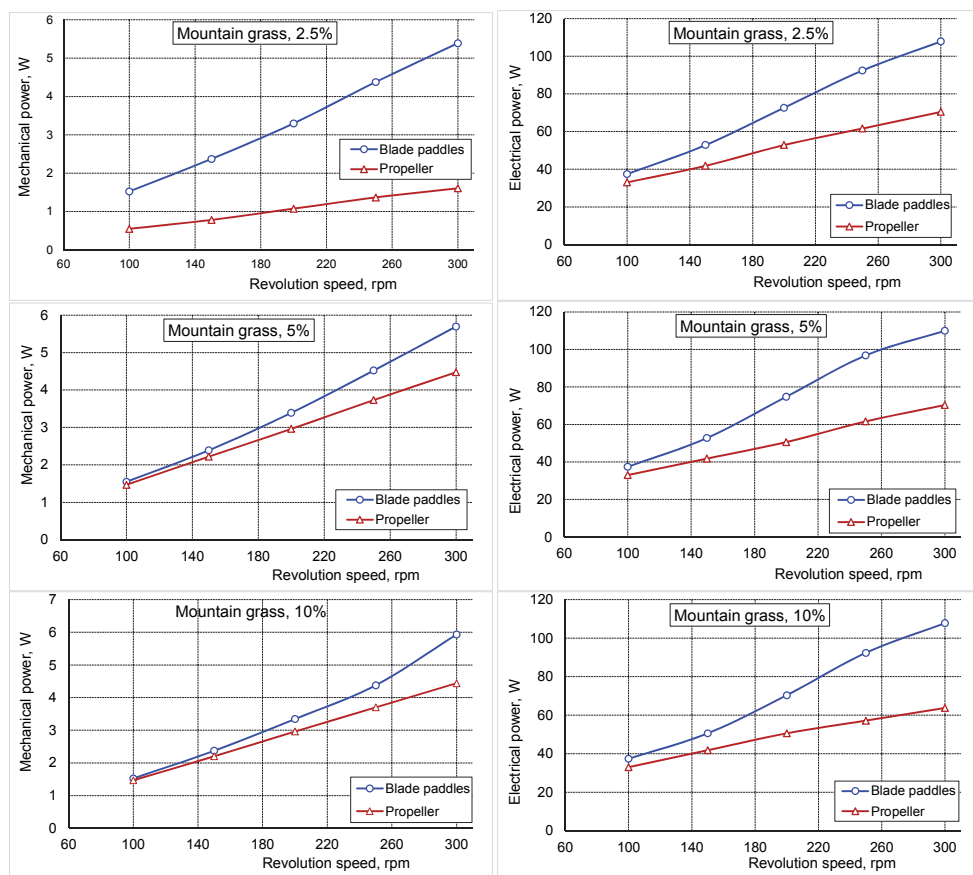


Fig. 4 Mechanical power variation, respectively electric power variation, in correlation with homogenizator type, for homogenization of mixed combination of grinded mountain grass and water

If we analyze fig. 5, it could be seen the differences between the electric power with homogenizator revolution, for all solid - liquid concentrations, for both types of grinded biomass, used during testes.

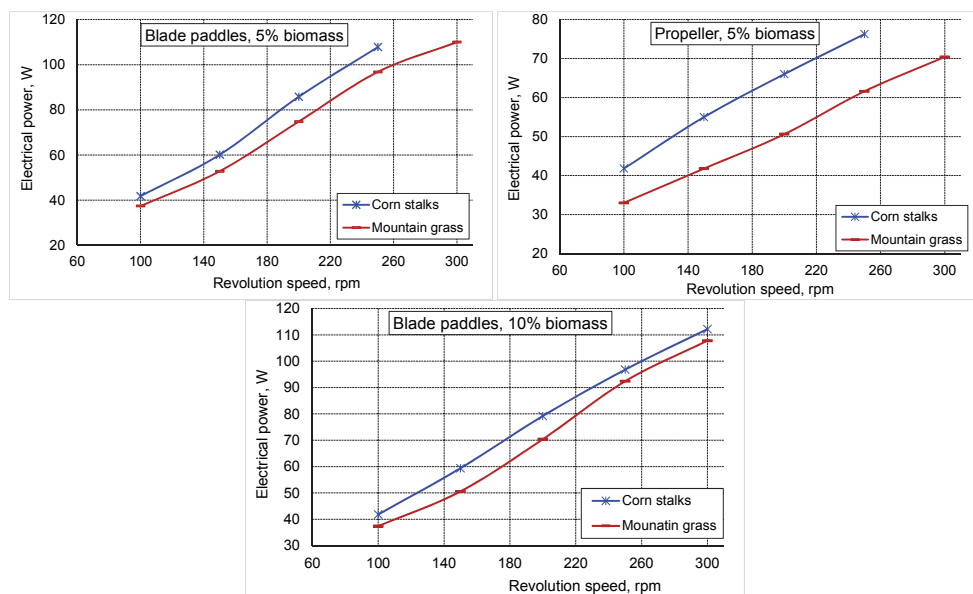


Fig. 5 Mechanical power variation, respectively electric power variation, in correlation with homogenizator revolution, and biomass type, during mixing with blade paddles homogenizator

CONCLUSIONS

Solid - liquid mixing homogenization based on biomass, in an anaerobic fermenter case, is very important in order to obtain an increased quantity of biogas. It is then necessary to know the power demand for grinded biomass homogenization, while using mechanical homogenizers, for choosing the according type of homogenizator, revolution homogenizator or the solid- liquid concentration.

In our paper, we used a lab mixer for highlighting the differences between the way of power registration (mechanical and electrical) and its variation with the mixing axel revolution, but also the differences between the mixers used, type of grinded biomass and its concentration in liquid.

For the concentration values used during tests, it could be highlighted the power variation (mechanical and electric) in correlation to the mixer type and revolution, but it could not be seen differences between the power demand in correlation to the solid concentration in water.

For mechanical power necessary for grinded biomass homogenization, no matter the biomass concentration in water, the values obtained were about 1.5 - 6 W, in correlation to mixer revolution, higher values being obtained for the blade paddles mixer.

There are significant differences between mechanical and electric power values, about 15 - 20 times, so the registration of power being very important. Our experimental results

can be used as a starting point for new experimental research regarding the needed power for biomass homogenization in anaerobic fermenter.

ACKNOWLEDGEMENT

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/132395 and with the support of the University "Politehnica" from Bucharest.

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ANAEROBIC DIGESTION OF VEGETAL BIOMASS USED AS SUBSTRATE FOR BIOGAS PRODUCTION

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ABSTRACT

Anaerobic digestion has been evaluated as one of the most energy-efficient and environmentally beneficial technology for bioenergy production. In the present paper, there was tested the alfalfa biomass in different concentrations and particles dimension, in order to establish the optimal concentration for obtaining biogas. This was comminuted to different granulations in a laboratory mill, then was added in various amounts in the same amount of water. To assess the suitability and profitability of biogas feedstock, laboratory tests consisted of determination of total suspended solids (TSS), pH, the refractive index (nD) and the substrate consumption.

Key words: biomass, anaerobic digestion, biogas

INTRODUCTION

Among the method of using biomass in order to obtain energy, biogas production through anaerobic digestion is presently the most common practice in Europe.

Anaerobic digestion is widely used to treat and recover energy from sludge from wastewater, biodegradable waste, agricultural waste and biodegradable waste from the food industry [10, 11].

Anaerobic digestion is a biological process in which organic matter is decomposed by an assortment of microbes under oxygen - free conditions and produces biogas (about 50 -75% CH₄ and 25 - 50% CO₂) [5]. Biogas can be used to produce heat, electricity, compressed natural gas (CNG) or liquefied natural gas (LNG). Solid fraction resulting from the anaerobic fermentation process, is called digestate, contains nitrogen and phosphorus and is widely used as a soil amendment.

The anaerobic digestion process can be carried out in a different content of total solids (TS). Thus, the anaerobic fermentation of liquid fraction is generally carried out at a TS

content of less than 15%, while the anaerobic fermentation of solid phase takes place at a TS content of more than 15%. High methane yields have been obtained in the case of anaerobic fermentation of liquid fraction due to the very good temperature control, good mass transfer provided by mixing process and dilution of inhibitors [9]. Studies in this area show that most of the agricultural biogas plants in Germany and Austria use as substrate grass silage in 50%, this being the second most frequent type of substrate used after maize silage [7]. Regarding the ensilage process of the substrate subjected to anaerobic fermentation, the researchers are still at the emerging stage. A series of parameters such as the substrate particle size, use of ensiling additives (lactic acid, salts or organic/inorganic acids) and ensiling duration influence the ensiling process and silage quality, this affecting directly or indirectly the biomethanation process. According to [2], a considerable reduction in biogas production was notified due to aerobic fermentation of grass silage used as substrate. Thus, immediately after opening the silage bale was recorded biogas production of about 500 l/kg, after 5 days from the bale opening biogas production decreased to 370 l/kg and after 30 days the biogas production reached only 250l/kg.

In practice, crop residues are usually mixed with animal manure, sludge from wastewater treatment plants and energy crops. This process is called co-digestion.

In European countries, pig manure is the main substrate for biogas plants. According to [6], about 300 Mt of manure are produced annually in Europe. The highest production of manure was recorded in Germany (49 Mt), followed by Spain (46 Mt) and Poland (33 Mt). However, it is well known that a too high concentration of swine manure in the substrate may result in the inhibition process due to the high concentration of ammonia.

In the last period, there have been conducted an increasing number of experiments aiming determining the production of biogas from anaerobic digestion of biomass, animal manure and other biodegradable waste [12, 15, 8].

Cuetos *et al* [4], conducted experiments using co-digestion of pig manure with crop residues consisting of corn, sunflower and rapeseed in different ratios: 75:25, 50:50 and 25:75 (as %VS). The highest methane yield was obtained for the 50:50 ratio with maize

(>40 l/gVS), while the lowest biogas production (<0.2 l/gVS) was recorded for sunflower at the 25:75 ratio due to the high lignin content.

Xie *et al.* [14], tested the co-digestion of pig manure with grass silage at five different ratios (1:0, 3:1, 1:1, 1:3, 0:1 gVS), at 35°C, for a period of 90 days. They reported that the highest methane yield was achieved at the 1:3 proportion (304.2 ml/gVS), respectively at 1:1 proportion (302.8 ml/gVS).

Another study related to the co-digestion was carried out by Bulkowska *et al.*, [3]. They tested the fermentation of silage crops (*Zea mays L.* and *Miscanthus sacchariflorus*) with 0%, 7.5%, 12.5% and 25% pig manure as a co-substrate. Results showed that the most stable and efficient anaerobic fermentation process was obtained using a proportion of 7.5% and 12.5% pig manure. The authors concluded that compared to crop silage alone, pig manure favored the production of biogas and methane; the highest production rates were obtained with 12.5% pig manure.

Zhang T. *et al.* [16], investigated biogas production by co-digestion of goat manure with three crop residues, namely, wheat straw, corn stalks and rice straw, under different mixing

ratios. Results showed that the combination of goat manure with corn stalks or rice straw significantly improved biogas production at all carbon-to-nitrogen (C/N) ratios. Goat manure(GM)/corn stalks (CS) (30:70), GM/CS (70:30), GM/rice straw (RS) (30:70) and GM/RS (50:50) produced the highest biogas yields from different after 55 days of fermentation.

The biogas production of biogas resulted from the anaerobic fermentation of organic fraction is considerably influenced by the substrate composition [1]. Even for the same species of biomass used, its composition can vary by geographical area, the season of harvest and the storage mode [13].

Thus, the characterization of substrate components used in anaerobic digestion process for obtaining biogas is very important to estimate the biogas production.

In the present paper, there was tested the alfalfa biomass in different concentrations, in order to establish the optimal concentration for obtaining biogas. To assess the suitability and profitability of biogas feedstock, laboratory tests consisted of determination of total suspended solids (TSS), pH, the refractive index (nD), the ash, the moisture and substrate consumption.

MATERIALS, METHODS AND PROCEDURE

Alfalfa plants, used during experiments, have been harvested at maturity, in 2013, from the mountain region Campulung Muscel, Arges County, Romania.

Feedstock preparation

Regarding the biomass processing, grinding was done with the help of a laboratory mill Grindomix GM-200 equipped with a tray and two stainless steel knives fixed at the bottom of a rotor, thus comminuting the material by impact of particles. For the comminuting of the alfalfa plants, the revolution speed was set at 5000 rpm and the grinding time was 1 min. Then, the granulometric analysis of the grinded material was performed using the sieve shaker VIPO model, equipped with five sieves overlapped in a decreasing order, fixed in a bloc, with oscillatory motion, for 3 minutes at 1500 oscillations/min.

Depending on the refusal remained on each of the sieves, there were formed four sorts of the tested material, as follows: the sort one was made up of material left on the sieves with mesh size of 1.6 mm, 2.5 mm and 3.15 mm; the second sort consisted of material left on the sieve with a mesh size of 1 mm; the third sort was made up of material left on the sieve with a mesh size of 0.71 mm and the last one was composed of material arrived in the collection box at the opposite end supply ($d = 0-0.71$ mm).

The proportion alfalfa – water material for each of sorts tested was 1:10; 1:15 respectively 1:20 (representing 10%, 6.7% respectively 5% concentration solid - liquid). Each sort of the test substrate was placed in the above proportions, and in the same quantity of water in Erlemeyer flasks (Fig. 1). After that, the Erlemeyer flasks were placed in the orbital incubator (Fig. 2) for a week at a temperature of 37 °C and the mixing rate was set at 150 oscillations/min.



Figure 1 Erlenmeyer flasks with different size of alfalfa



Figure 2 The orbital incubator

Methods of analysis

The concentration of total suspended solids (TSS) and refractive index (nD) was measured using an ABBE refractometer. Measured liquid samples were taken at intervals of 24 hours of each sort analyzed. The pH of the liquid samples was determined using a pH meter type Hanna. The initial pH of the samples tested was about 6.4 units.

RESULTS AND DISCUSSION

In the tables 1 – 4 there are given the data recorded during the experiments for each parameter followed (TSS, pH, nD and substrate consumption) for each type of sort in the time interval 24 h - 144 h. Based on the obtained data, were made graphs in Fig. 3-7.

Table 1 Characteristics of the tested substrate after 24 h of fermentation

	Sort 1			Sort 2			Sort 3			Sort 4		
	1:10	1:15	1:20	1:10	1:15	1:20	1:10	1:15	1:20	1:10	1:15	1:20
pH	5,25	5,79	6,22	5,19	5,15	5,91	4,99	5,27	5,59	5,49	5,82	5,79
Substrate consumption (g)	99,79	99,72	99,83	99,75	99,08	99,79	99,74	99,75	99,8	99,73	99,73	99,77

Table 2 Characteristics of the tested substrate after 48 h of fermentation

	Sort 1			Sort 2			Sort 3			Sort 4		
	1:10	1:15	1:20	1:10	1:15	1:20	1:10	1:15	1:20	1:10	1:15	1:20
TSS (%)	2.9	1.8	1.3	3	2.6	2.2	3.3	2.6	2	4.6	3.1	2.7
pH	5.51	6.59	6.87	5.24	5.43	6	4.91	5.41	6.7	5.66	6.17	6.57
nD	1.3372	1.3356	1.3356	1.3373	1.3368	1.3362	1.3378	1.3367	1.3359	1.3356	1.3349	1.3356
Substrate consumption (g)	97.77	97.81	97.6	97.97	97.67	97.72	97.63	97.68	97.83	97.05	97.46	97.46

Table 3 Characteristics of the tested substrate after 120 h of fermentation

	Sort 1			Sort 2			Sort 3			Sort 4		
	1:10	1:15	1:20	1:10	1:15	1:20	1:10	1:15	1:20	1:10	1:15	1:20
TSS (%)	2.8	1.8	1.2	1.8	1.9	1.2	3.1	2.4	1.4	2.4	1.8	1.9
pH	5.8	6.97	7.22	5.67	6.27	6.27	5.39	5.75	6.76	5.79	5.66	5.72
nD	1.337	1.3354	1.3348	1.3356	1.3357	1.3347	1.3374	1.3365	1.335	1.3364	1.3356	1.3357
Substrate consumption (g)	96.6	96.49	96.23	96.22	95.82	96.24	96.23	95.75	95.81	94.99	94.56	95.6

Table 4 Characteristics of the tested substrate after 144 h of fermentation

	Sort 1			Sort 2			Sort 3			Sort 4		
	1:10	1:15	1:20	1:10	1:15	1:20	1:10	1:15	1:20	1:10	1:15	1:20
TSS (%)	2,7	1,7	0,7	1,4	1,8	1,1	3	1,9	1,3	1,8	1,9	1,5
pH	6,35	7,35	7,47	6,71	6,82	6,82	6,15	6,41	6,97	6,33	6,36	6,57
nD	1,3369	1,3354	1,334	1,335	1,3356	1,3345	1,3373	1,3358	1,3354	1,3356	1,3349	1,3356
Substrate consumption (g)	95,04	95,1	94,39	94,73	94,43	94,94	94,58	94,21	94,29	93,55	92,81	94,01

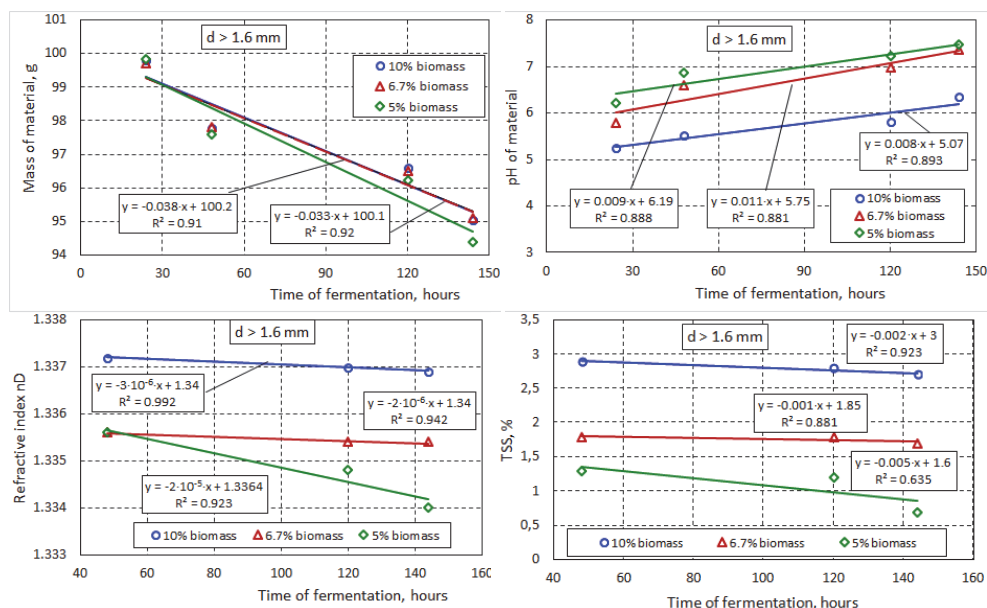


Fig. 3 Variation of fermentation parameters (mass of material, pH, total suspended solids, refractive index) with time of fermentation, for large fraction of grinded alfalfa

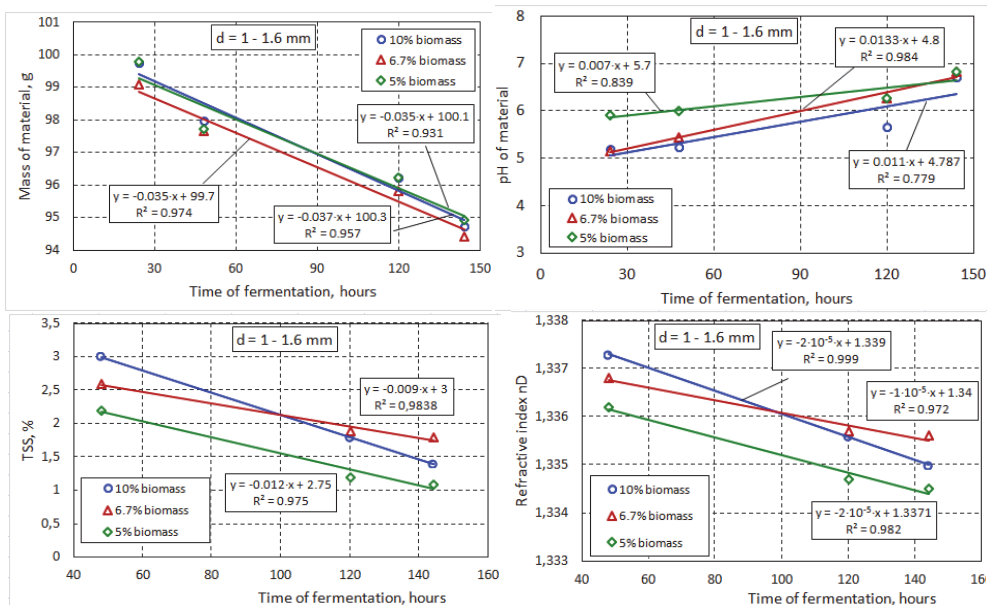


Fig. 4 Variation of fermentation parameters (mass of material, pH, total suspended solids, refractive index) with time of fermentation, for medium fraction of grinded alfalfa

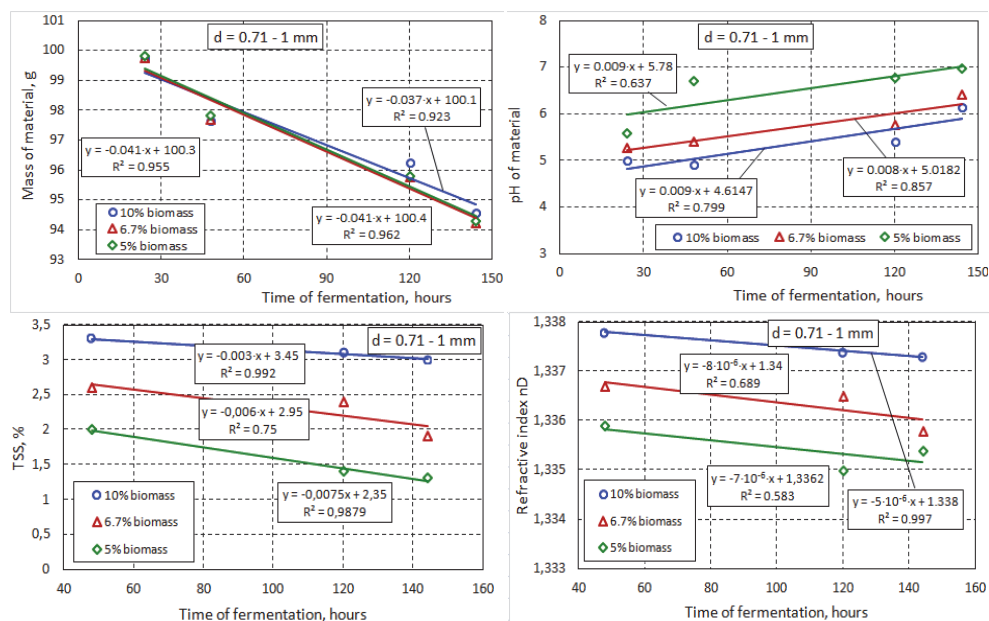


Fig. 5 Variation of fermentation parameters (mass of material, pH, total suspended solids, refractive index) with time of fermentation, for fraction $d=0.71-1$ mm of grinded alfalfa

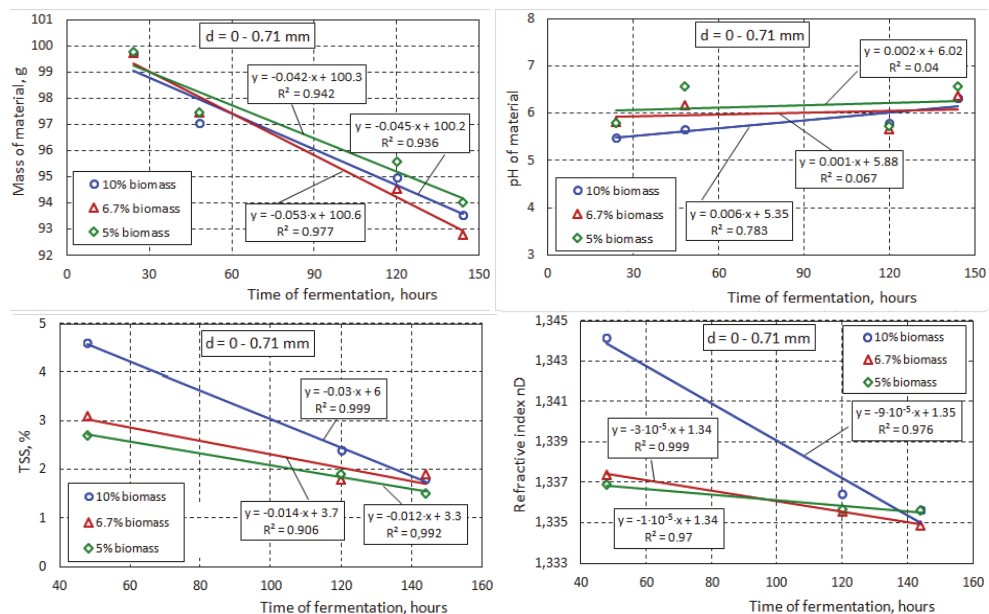


Fig.6 Variation of fermentation parameters (mass of material, pH, total suspended solids, refractive index) with time of fermentation, for small fraction of grinded alfalfa

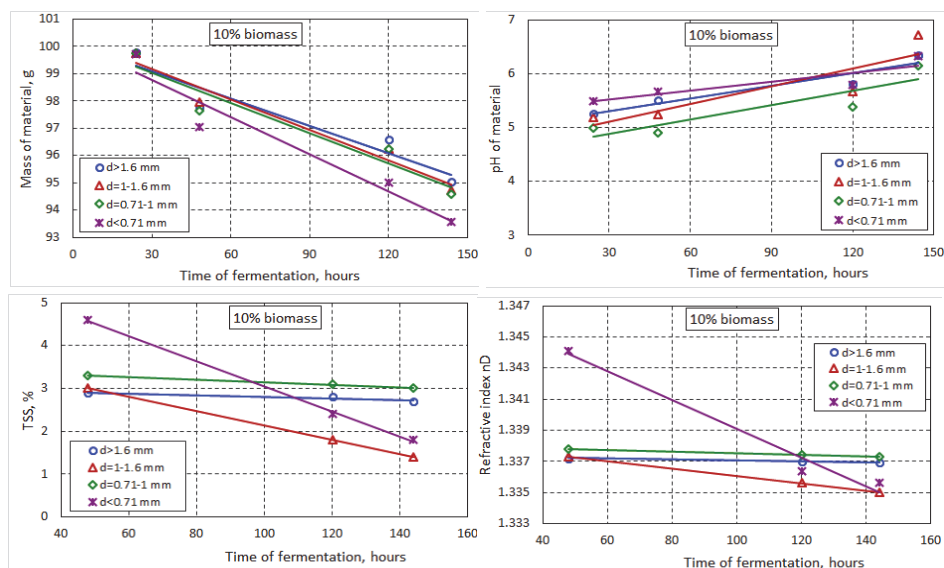


Fig. 7 Variation of fermentation parameters for concentration of 10% alfalfa

The mass of the vegetal substrate decreased during the 144 hours of incubation at 37°C, due to release of gases produced after the substrate fermentation by about 5% for all samples. The decrease by a few percent can also be caused due to the evaporation at this value of temperature. The substrate consumption by the way of anaerobic decomposition is relatively low due to the use of one type of nutrient, of vegetable origin existing in alfalfa biomass. The symbiotic microorganisms transform the organic material under oxygen-free conditions into biogas, cell matter and microbial metabolites.

The pH of liquid samples had an ascending tendency, characteristic for this type of fermentation. In the first days, the pH value decreases slightly from the initial pH by 6.4 units to values between 4-5 (after 24 hours) because of the accumulation of organic acids; after 48 hours the pH values begin to rise and at the end of the incubation period values ranging from 6-7 units. In the first part of the process act hydrolytic and acidogenic microorganisms (*Streptococcus*, *Lactobacillus*, *Bacillus*, *Escherichia coli*, *Salmonella*) to produce organic acids, such as acetic, propionic, butyric, fatty acids, alcohols. In the second part of the process act the methanogenic bacteria of the genera *Methanosarcina*, *Methanospirillum* and others that prefers slightly alkaline environment. After 3 days of incubation, pH values begin to rise due to development of other types of fermentations, including the methanogenic one.

The initial TSS values are different depending on the amount of alfalfa used as a substrate. TSS value refers to the amount of soluble compounds released into the fermentation medium from the vegetal material, mainly substances with low mass. In addition, soluble substances could be formed by the hydrolysis reactions due to the exoenzymes released by hydrolytic bacteria in order to degradate the macromolecular substrate at assimilable compounds with low mass. In time, as seen in all cases, the

bacterial populations consume nutrients from the medium and the TSS values decreased significantly.

CONCLUSIONS

The anaerobic fermentation process proved to be an effective biological process for treating the organic wastes derived from the agricultural and zootechnic sector.

From the experiments conducted, it was found that anaerobic fermentation process is significantly influenced by both particle size substrate (alfalfa) and the amount of substrate used. The highest values of TSS (%) were recorded for samples to which was used substrate particle size between 0 - 0.71 mm.

During the 144 hours of incubation, it was found a decrease in the total mass of the sample by 5%, due to fermentative processes and eliminating water vapors.

The substrate consumption determined by weighing, as expected, had higher values for the substrate with the smallest particle size (0-0.71mm). For example, for the 10% (w /w) the substrate mass decreased from 99.7 g to 93.5 g value.

The pH values decreased after the first 48 hours from the initial value of 6.4 units to about 5 units, due the fermentation that produces organic acids such as acetic, propionic, and butyric; after this period, the trend was slightly increasing, it has definite values between 6-7 units.

AKNOWLEDGEMENT

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/134398.

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COMPACTING PROCESS AND MATHEMATICAL ANALYSIS OF MISCANTHUS BRIQUETTES EXPANSION

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SUMMARY

*In the last hundred years, man intensively exploited the primary energy sources (coal, petroleum and natural gases), which led to a major contribution of CO₂ in the atmosphere, much above the possibilities of the "planet's lungs" (plants and trees in the terrestrial ecosystem) to consume during their growing period. That is why, scientists recommend more and more, in the last period, the use of renewable bio-fuels coming from vegetal biomass. In this category falls the plant *Miscanthus x giganteus* which becomes a viable energy alternative to the conventional energy sources. The paper presents the compaction study of *Miscanthus x giganteus* plant by means of an experimental installation in laboratory conditions. At the same time, the asymptotic behavior of the expansion (the dimensional evolution in a chosen period of time) of the briquettes made through a densification process, the data being processed using specialized mathematical programs in order to obtain an adequate mathematical equation.*

Key words: *Miscanthus x giganteus*, densification, briquettes, relaxation in time, mathematical model

INTRODUCTION

Biomass, in its original form, is hard to be successfully used as fuel in large dimension applications, because it is rather voluminous, damp and dispersed. Biomass densification represents a technological solution for factories converting residues into fuel Tumuluru et al

(2011). These technologies are also known by the name of granulation, briquetting or agglomeration, which should improve the handling characteristics of materials for transport, storage, etc., pelletizing and briquetting are processes which have been using for many years in various countries.

In a broad sense of the word, biomass is represented by the plant organic matter, animal metabolic residues (manure) as well as microorganisms. In a strict sense, agricultural biomass includes secondary products from the plants cultivated such as: straws, corn cobs, stalks (sun flower, soy), leaves (beet), pods (soy, beans), shells (walnuts, peanuts), pips (plum, peach, apricot) and manure from animal farms, Danciu A. et al (2010). Besides the agricultural biomass sources there are the forestry ones: primary and secondary material from exploiting forests and resinous and deciduous plantations.

In this context, biomass can be burned to generate heat and electricity, or it can be used as coarse material for the production of biofuels (biodiesel, bioethanol) and some chemical compounds. Biomass is biodegradable and renewable. Biomass production represents an expanding field due the increasing interest in alternative energy sources.

Producing plant biomass at large scale implies growing numerous species of plants, the most important being elephant grass (*Miscanthus x giganteus*), Switchgrass (*Panicum virgatum*), hemp (*Canabis sativa*), corn (*Zea mays*), poplar (*Populus sp.*), willow (*Salix sp.*), sorghum (*Sorghum sp.*) and sugar cane (*Saccharum officinarum*), Sorică et al (2009).

Therefore, biomass represents an important component in the carbon cycle. Carbon from the atmosphere is transformed into biological matter (biomass) through the photosynthesis process. By death or combustion of plant matter, carbon goes back into the atmosphere as carbon dioxide, Tudora E. (2009). This circuit lasts a relatively short period of time, and the biomass used as energy source can be constantly renewed by re -cultivation. Therefore, biomass is a renewable energy source, sometimes called “carbon- neutral fuel”, whose usage still contributes sometimes to the global warming phenomenon. These unwanted effects take place when disturbances occur in the natural balance of carbon, generated by massive deforestation, excessive urbanization, etc.

When biomass is used as fuel, taking the place of the fossil ones, the same quantity of carbon dioxide is released into the atmosphere. In the cases when biomass is used to produce energy, it is considered as a carbon-neutral fuel, because of the drastic reduction of gas emissions into the atmosphere that determines producing methane instead of CO₂. Carbon represents approximately 50% out of the dry plant mass and it is part of the atmospheric carbon cycle. Biomass fixes CO₂ from the atmosphere during its growth, after its own carbon is released in the form of a carbon dioxide (CO₂) and methane (CH₄) mixture, depending on the last use of the plant material.

Taking into account the considerations presented above, we can say that a novel alternative for the Romanian area is the cultivation of *Miscanthus* plant. This is a very tall perennial plant (at maturity it reaches 3.5 m), increasingly popular in Europe as a source of green energy. It grows best in a cool climate. It can be harvested once year using technical equipment currently used in the classic agriculture (for example equipment for harvesting sugar cane). It is often found in its hybrid form, namely *Miscanthus x giganteus*, Voicu E. et al (2010).

For the cultivation of elephant grass, the soils rich in humus and clay, with a good water supply are the most suitable ones. Unsuitable soils are the very heavy ones, with the tendency of hardening – the soil has to be damp – without stationary water up to 1 m in depth (the pH value between 5 and 8). Weeds near the plant roots do not play a dominant role, they do not affect the plant. It can be cultivated in some climatic regions, especially in corn layers (cereals), having a soil production capacity starting from 60 which can bring a good production. Weaker soils also have obtained satisfactory results.

When growing a *Miscanthus x giganteus* plantation (fig. 1), besides the soil's reliability, of major importance is the volume of precipitation and distribution until the middle of September. Precipitations of 700-900 mm with a good distribution in the vegetation period are ideal. At lower precipitations, around 500mm minimum, the productivity decreases. After a long period of draught, the loss of leaves may occur, but they will continue to grow if it rains or if the plants are irrigated. The maximum growth period is between the months of June and August.

This plant is especially suited for producing pellets, because it has low humidity, a property also reached by the other pellets at the end of the manufacturing process, no matter the raw material used, but lately, densification technologies are used to turn it into briquettes. The annual production (calculated after drying the harvested plant in furnaces) is of 10-20 tons per hectare.



Fig. 1 Experimental *Miscanthus x giganteus* crop at INMA Bucharest

The densification process in the form of briquettes of agricultural biomass is an activity with a high potential both in Romania, and also in Eastern Europe countries. William Smith was the first to issue a patent in United States (1880) for biomass densification. Using a steam hammer (at 60° C), Smith has compacted sawdust wastes.

Tumuluru et al (2011) suggest that the biomass densification process during pelletizing can be attributed to the elastic and plastic deformation of particles at high pressures. According to their studies, the two important aspects that are to be considered during pelletizing are, Mani et al (2006):

- the capacity to form pellets, with a considerable mechanical resistance;

- the capacity to increase the density of the process.

During densification, these solid punctures are developed by numerous chemical reactions such as: solidifying the binder, solidifying the melted substances or crystallizing the dissolved material, Repsa et al (2012). The pressures applied during densification also reduce the melting point for the particles and make them move towards each other, thus increasing the contact surface and changing the melting point at a new balanced level, Repsa et al (2011).

The new and renewable energy sources represent in the present time only 6% out of the EU energy balance, and if this trend is kept, they will cover only 9% of the total consumption by 2030.

Thus, in December 2008, the European Council adopted an integrated policy for energy and climate changes that includes ambitious targets for the year 2020 hoping to set Europe on the path of a sustainable future, with the reduction of carbon, efficient energy savings by Danciu A. et al (2010):

- Reducing greenhouse gas emission by 20% (compared to 1990);
- Reducing energy consumption by 20% through increased energy efficiency;
- Covering 20% of the energy consumption from renewable energy sources.

Taking all these aspects into account, theoretical and experimental research on the agricultural biomass densification process, in the case of *Miscanthus x giganteus* is impetuously necessary and benefic.

The paper presents a mathematical model of the process of biomass densification (*Miscanthus x giganteus*) depending on the expansion in time of the experimental briquettes made, the moisture and granulation of the raw material, respectively the compaction force. The expansion of experimental *Miscanthus x giganteus* briquettes represents the loss of cohesion for the component particles and is a quality index for the densification process. Shore hardness is the resistance to penetration opposed by a solid body, in this case *Miscanthus x giganteus* briquettes to the external mechanical penetrating action. This represents a new approach in the innovative research on the quality of the process of biomass densification.

MATERIALS AND METHODS

To achieve the densification process for *Miscanthus x giganteus* biomass an experimental installation for biomass compaction at a reduced scale, was used. It is represented by a powerful machine with a maximum capacity of 100 kN. The experimental installation is assisted by a computer, and through specialized software program it is possible to vary the forward speed of the piston and the data are saved while performing the tests. The installation for the densification of agricultural biomass is presented in figure 2. The force-deformation curve (relative movement of the piston rod) appears on the monitor of the data acquisition installation (fig. 2 – right side).

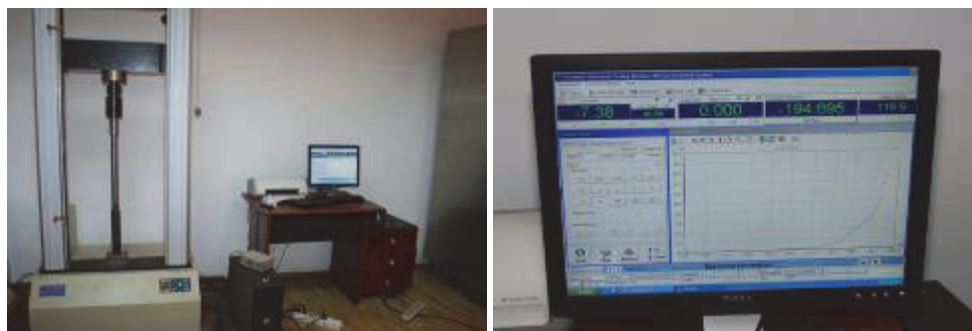


Fig. 2 Installation for biomass compaction at a reduced scale and the densification force-deformation curve

Thus, for the densification process, the following entry data were determined:

- Raw material granulation.

The following granulations were used for the four sizes of biomass: 1.6 mm, 2 mm, 3 mm and 4mm. The granulation was determined using a RETSCH AS 200 Basic sieving system at an amplitude of 50 Hz, for a 5 minutes interval.

- Raw material humidity.

In the experimental plan, for the compaction of the four sizes of biomass the following values for the entry humidity of the raw material were used: 10%, 12%, 14% and 17%. For the determination of humidity, the KERN moisture analyzer was used.

- Raw material density.

For each densification process of the four sizes of biomass, the raw material density was calculated, best named volume mass.

- Matrix temperature.

For the present moment of conducting the experimental plan, a temperature of 15°C for the pressure cylinder was used.

The control parameters for the densification process for the two types of biomass used were:

- The densification force.

The following densification forces were used in conducting the densification process: 40 kN, 50 kN, 60 kN, 70 kN, 80 kN, 90 kN.

- The moving speed of the piston during de densification process.

The speed used to charge the piston was in the range of 10-50 MPa/s.

For each densification process, the following exit data or quality data for the obtained briquettes have been determined:

- Briquette density.

After each densification process for the two types of biomass, the density or better named volume mass was determined for each briquette made from *Miscanthus x giganteus*.

- The capacity to maintain cohesion.

Each *Miscanthus x giganteus* and sawdust briquette will be kept under observation for two months to observe the cohesion capacity. Thus, size measurements will be taken at the initial moment and after that from 5 to 5 days up to 60 days.

The behavior of briquettes made from biomass residues formed by compression in specially designed devices, is important especially in establishing the maximum possible storage time during which this type of material can be handled as a solid, coherent material. Packaging briquettes in different biodegradable or not packages can lengthen the period for efficient storage (when the briquettes can be handled as solid material), but not by a very long time. This necessity generated the study of maintaining the solid qualities of briquettes over the course of time. The dependence of the length of the period of time in which the briquette does not break or does not transform into powder (but can lose material) remaining able to be handled as a solid material, is one of the objectives of this chapter. It is aimed to determine the influence of the varied work parameters during the experiments on the solidity and integrity of the briquette formed: the compression force, (F), the loading speed, (v), the humidity of the material submitted to compression, (u) and its granulation, (g).

In order to determine the dependence of the variation in time of the briquettes quality were chosen as measurements for it, the length expansion of briquettes (a characteristic analyzed in this paper) and the Shore hardness. By expansion it was understood the length of the briquette, so named because of its tendency to grow, Ivanova et al (2013). It was conventionally considered that the briquettes that were broken have had, until the end of the observation period, the same size from the moment of breaking. The Shore hardness is a standardized characteristic.

RESULTS

The experimental data took place for: a 60 days period of observation concerning the expansion (with 13 measuring days); a 30 days period of observation for Shore hardness (with only 2 measuring points). It can be observed that 72 experiments were carried out.

Taking into consideration the asymptotic behavior of the expansion, an exponential approximation function was chosen in the form:

$$\Lambda(t, l_0, F, v, u, g, \lambda, \eta) = \lambda \cdot e^{\eta \cdot \alpha(F, v, u, g)t} + l_0 - \lambda, \quad (1)$$

where:

- λ - parameter that is determined from experimental data using the method of the least squares;

- η - coefficient which is determined as λ ; non -dimensional:

$$\psi(\lambda, \eta) = \sum_{i=1}^{72} \sum_{j=1}^{13} (\Lambda(t_j, l_{0i}, F_i, v_i, u_i, g_i, \lambda, \eta) - D_{i,j})^2, \quad (2)$$

where:

- l_0 – initial length of column of material used;
- t – time within which the compacting process is performed;
- D_{ij} – expansions experimentally noticed for samples $i=1, 2, \dots, 72$ in the 13 measuring days.

The variables with indices are the values of the contiguous variables for the 72 experiments ($i = 1 \dots 72$) and for the 13 observation times, $j = 1 \dots 13$.

The α appearing as an argument of the exponential function depends on the parameters varied in the process: the compression force, F , the loading speed, v , the humidity of the material submitted to compression, u and its granulation, g . The form of this dependence of the α function on the parameters varied in the process was chosen so that the whole argument of the exponential function to be dimensionless. One of the simplest combinations is the one chosen in the form:

$$\alpha(F, v, u, g) = u \cdot \frac{v \cdot g^2}{F}. \quad (3)$$

Also in the (2) functional, the D matrix is the matrix of the variation on the 72 experiments of the briquettes expansion seen in the 13 observation times. Minimizing the (2) functional with the start point $\lambda = 0.06$ and $\eta = -0.25$, the optimal values for the two parameters are obtained, so that the interpolation curve (fig. 3) should be “the closest” to all experimental points, $\lambda = -0.051$ and $\eta = -0.001569$.

Thus, for the experimental data of briquettes from sawdust of *Miscanthus x giganteus*, the interpolation function of the experimental data has the form:

$$\Delta(t, l_0, F, v, u, g) = -0.051 \cdot e^{-0.001569 \cdot u \cdot \frac{v \cdot g^2}{F} t} + l_0 - \lambda \quad (4)$$

For a set of experimental data, the comparative graphic representation of the experimental data and of the values of the interpolation function is shown in fig. 3.

Figure 4 shows the variation in time of the expansion for five values of the maximum compression force equidistant chosen in the experimental interval and average values for the others parameters appropriate to the compression process.

In figure 5, the same type of graphic representation is made for different values of the loading speed in the compression pressure.

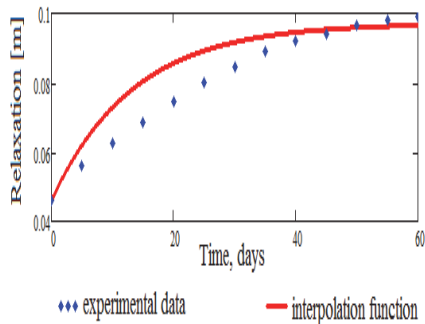


Fig. 3 Variation of experimental data and the interpolated data

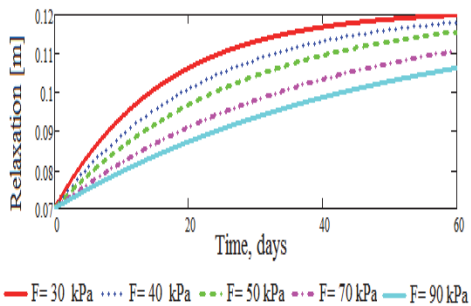


Fig.4 Briquette relaxation depending on the densification force

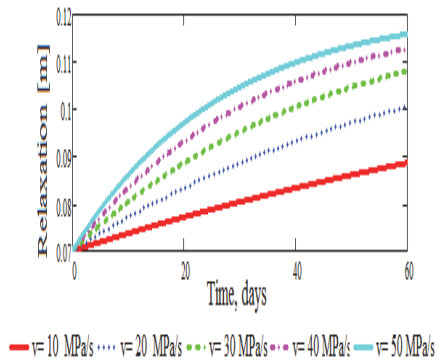


Fig. 5 Variation of briquette expansion with the densification speed

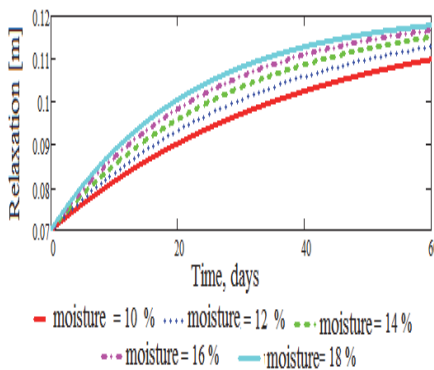


Fig. 6 Briquette expansion depending on the entry humidity of the raw material

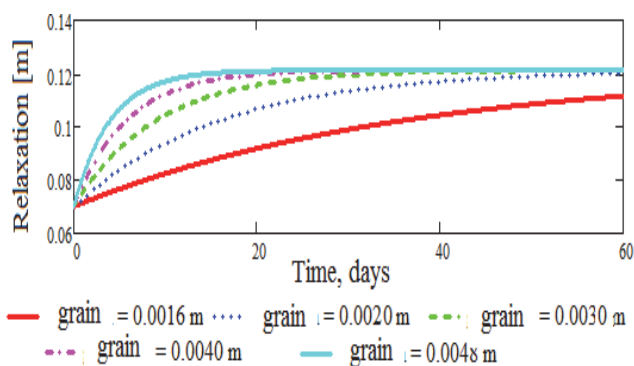


Fig. 7 Variation of briquette expansion with granulation

CONCLUSIONS

Function of briquette expansion has an exponential form which greatly depends on compacting force, densification speed, material humidity and its granulation.

Taking into account the experimenting conditions used for compacting process of biomass obtained from *Miscanthus x giganteus*, using an installation which allows the control of applied force, for the 72 tests obtained and monitoring the briquettes expansion process during 60 days, it has been noticed that the force:

- decreases proportionally with compaction force applied, in case of a maximum applied force of 90 kPa the expansion being by about 18% smaller than in case of a force of 30 kPa;
- increases along with compacting speed, varying from 9 mm ($v = 10$ MPa/s) to a maximum of 11.6 mm ($v = 50$ MPa/s), namely by approx. 30%;
- depends on humidity before briquetting, increasing from 10.8 mm (at 10% humidity) up to 11.8 mm (humidity of 18%), namely by approx. 10%;
- increases along with granulation degree of compacted biomass, from 10.5 mm (at 1.6 mm granulation) at 12 mm (at 4.8 mm granulation), namely about 14%.

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DETERMINATION OF CALORIFIC VALUE OF BRIQUETTES OBTAINED USING INNER AND OUTER SHELLS OF PISTACHIO NUTS

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SUMMARY

In this research, moisture content, ash ratio and calorific values of briquettes were determined for briquetted inner and outer shells of pistachio nuts after the processing of pistachio nuts that were dried and separated from shell parts during processing. Inner and outer shells of pistachio nuts were grinded and formed into briquette form. Briquettes were prepared using olive prina as additive with %20, %30 and %40 ratio and were compressed using briquetting machine. At the end of the briquetting process, briquettes of 100 mm in diameter and the length of 10-30 cm were obtained. Moisture and ash content with calorific values of samples which were formed into briquette were determined. As a result of these evaluations, improvements of physical features were observed in addition to the increase of briquette's olive prina ratios obtained in consequence of briquetting of pistachio shells by being mixed olive prina. It was determined that increasing of olive prina rate decreased calorific value.

Key words: Pistachio shell, Biomass, Briquettes, Energy

INTRODUCTION

According to 2012 data that is the most current data of The United Nations Food and Agriculture Organization (FAO); Iran is the leader state in production of pistachio nuts throughout the world. United States of America has increased production volume by improving production techniques in recent years and has become a rival to Iran. Turkey

also ranks in third line in seasons where there are so many productions with floating production structure. According to 2012 data, Turkey's pistachio production was 150.000 tones (Anonymous, 2012). Production values of pistachio nuts produced in Turkey were given as dry shelled pistachios. Dry shelled pistachio nuts consist of 12% of outer red shells and consist of 42% inner hard shells. Based on these values, 18.000 tones dry red shells and 63.000 tones inner hard shells have been revealed in Turkey.

Agricultural and domestic wastes have been used in order to contribute energy needs by being assessed with recycling system in many developed countries in the world. One of the methods applied so that agricultural wastes are assessed as an energy source is transforming them into forms that have high density and low moisture content in order to facilitate storage and conveyance of such wastes. With this purpose, more efficient usage of agricultural and domestic wastes is storing of them as briquetted and mobilization becomes easier.

Briquetting is a procedure of adequately fragmented material's compressing in the ways more than 25 mm in diameter. Biomass briquetting density has been increased from 100/200 kg/m³ to 1200 kg/m³. By means of briquetting procedure, characteristics of biomass have been improved, volumetric calorific value has been increased, transportation costs have been decreased, storage costs have been decreased. Briquettes can be burned easily in special stoves and due to changing of combustion characteristics particle emissions released into the atmosphere have reduced and better fuel has been obtained in the same size and shape (Kürklü ve Bilgin, 2005).

In this research, some physical and chemical properties of pistachio's inner and outer shell were determined. It was aimed that briquetting of inner and outer pistachio shells, revealing of one of different usage area of agricultural waste obtained after agricultural production and determination of changing of calorific values of briquette samples obtained after drying, grinding and mixing with olive prina.

MATERIAL AND METHOD

Material

In this research, inner and outer shells of Red type pistachio nuts were used (Figure 1a, 1b). Pistachio shells were grinded using 32-blade electric hammer mill that is driven by 2 kW electric motor (Figure 3). Inner and outer shells were briquetted after mixing with 20%, 30% and 50% rates olive prina. No adhesive agent were used during briquetting. At the end of the briquetting, briquettes which are about 100 mm in diameter and 10 - 20 cm in the length were obtained.

Briquetting machine with auger type screw briquetting technology was used for briquetting of materials (Figure 2). In helical screw press technology, material was being removed by the help of a screw by being compressed into a narrower mold. Produced briquettes have been in different forms depending on whether the mold passing through is round or not. Helical shaft, working in a similar way with shell meat mincing machine in screw presses, performs the compression process turning slightly in a conical mold.



Figure 1 Outer shell of pistachio (thin-red) (a), inner shell (thick-yellow) (b) and grinded form of the shells (c)



Figurel 2 Briquetting machine used in experiments

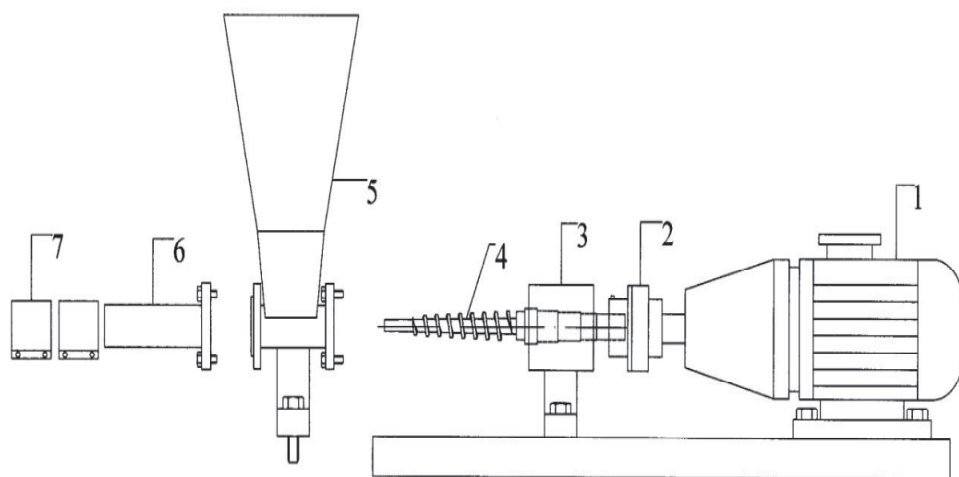


Figure 3 Conical twist type briquetting machine and its components 1. Elctric engine and gearbox 2- Coupling Connection 3- Shaft bearing 4- Conical twist shaft 5- Material storage 6- Conical mold 7- Plate type heater (Bilgin, 2008)

Drying oven (oven) was used for determination of moisture content of agricultural wastes and briquettes. Muffle furnace was used to determine ash content. Precision balance was used to perform the weight measurements of pistachio shells and briquettes. Calorific value measurements were conducted using a calorimeter device (IKA brand) that can perform up to 40.000 Joule. This device performs measurements in accordance with EN 61010, EN 50082, EN 55014 ve EN 60555 standards.

Method

With the purpose of determining moisture content of pistachio nuts which were reduced in size, firstly samples were waited in an oven of Thermocenter brand for 24 hours. Weights of samples before drying and after drying were found. Moisture content of samples were calculated using these weight data. Pistachio shells reduced in size using hammer mill were briquetted by briquetting machine for getting briquette. Olive prina with 20%, 30% ve 40% ratios were used as additive materials. Any adhesive material for briquetting was not used. As a result of briquetting, briquettes approximately 100 mm in diameter and in the length of 20-30 cm were obtained. The briquettes prepared using different ratios of olive prina were given in Figure 4.

With the purpose of determining ash content, samples were firstly dried in drying oven, then they were burned in the muffle furnace at the temperature of 550°C until the weight becomes stabile. Lower heating values of briquettes obtained by mixing pistachio shells with olive prina with different portions were measured using adiabatic calorimetry device in accordance with ASTM D 5865–04 standards. Before the test, briquettes were broken into pieces and moisture content of these samples were removed by witting in 105°C for 24 hours. In calorific value tests, dried samples that were prepared as 1 g were burned in a

calorimeter bomb in oxygen environment within the standard conditions. Calorific value was appointed depending on increase in water temperature in the calorimeter vessel and the average actual thermal capacity. Calorific value was calculated by observing heat before combustion, during combustion and after combustion and applying them corrections of thermo-chemical and calorific exchanges.



Figure 4 The briquettes obtained by mixing pistachio shells with olive prina

RESULTS AND CONCLUSIONS

Moisture content values for pistachio inner and outer shells were given in Table 1. According to drying procedure conducted by taking 10 gr samples from pistachio inner and outer shells, weights. Inner and outer shell moisture contents were determined as 5,4%, 7,3 %, respectively.

Weight values obtained as a result of combustion performed for purpose of determining ash content of pistachio inner and outer shells and briquettes were tabulated in Table 2. Experiments were carried out by taking 10 gr samples to determine of the ash content of pistachio inner and outer shell. As a result of combustion procedure, inner shell weight was measured as 0,192 gr, outer shell weight was found as 0,503 gr.

Table 1 Moisture content values of pistachio inner and outer shells

Material name	Before drying (gr)	After drying (gr)	Moisture content
Inner shell	10	9,46	% 5,4
Outer shell	10	9,22	% 7,3

Table 2 Ash content of pistachio shell

Material	Initial weight (g)	Weight after combustion (g)	Weight difference (g)	Ash content (%)
Inner shell	10	0,192	9,808	1,92
Outer shell	10	0,503	9,497	5,03
Sample mixed with 20% olive prina	50	2,755	47,245	5,51
Sample mixed with 30% olive prina	50	2,763	47,237	5,52
Sample mixed with 40% olive prina	50	2,360	47,640	4,72

When the ash contents of briquettes obtained by composition with olive prina were examined, no significant differences among samples that mixed different prina ratios were found. The ash content of briquettes obtained in this research was found close to ash content of agricultural wastes that were determined performed in the previous studies. Furthermore, ash contents of lignite coal is much lower compared to those values of agricultural wastes (Grover and Mishra 1996, Yalçın and et al. 1996, Acaroğlu and et al. 2002, Kürklü and Bilgin 2007).

Calorific Values of Briquettes

Lower heating values of briquettes obtained by mixing pistachio shells with olive prina in different portions determined by means of adiabatic calorimetry device in accordance with ASTM D 5865–04 standards were given in Table 3. In this Table, calorific values of briquettes obtained from grinded inner shell, outer shell and only olive prina were presented for comparison.

It has been determined in heating value measurements that calorific value of pistachio shells alone was found higher compared to samples prepared by mixing prina. The calorific values of inner shell and outer shell were found rather close. While the increase in the proportion of olive prina in the briquette leads to a positive result in terms of briquette quality other tests, it leads to negative results in terms of calorific value. This can be explained with comparison of calorific value of pistachio shells and prina alone. Calorific value of pistachio shells was found higher than calorific value of olive prina as seen in Table 3.

Table 3 Lower calorific values of briquettes obtained from pistachio shells, olive prina and mixing of shells and prina

BRIQUETTE	CALORIFIC VALUE (cal/g)
Inner shell	4494 (18,79)
Outer shell	4454 (18,62)
100% Olive Prina	2994 (12,52)
20% Ratio of Olive Prina	3735 (15,62)
30% Ratio of Olive Prina	3674 (15,36)
40% Ratio of Olive Prina	3312 (13,85)

Lower calorific value of briquettes obtained from pistachio shells were compared with lower calorific value given for other agricultural products in the researches made by Ünal and Alibaş (2002), Topal and et al. (2003), Başçetinçelik and et al. (2005) and Bilgin (2008). Briquettes obtained from pistachio shells can be considered to be used as energy source in the heating systems because of their high calorific values. It was determined that except from briquettes prepared using ratio of 40% olive prina, calorific values of other briquette samples have exceeded the lower calorific value (15.49 MJ/kg) determined for biomass briquettes in accordance with air pollution control legislation.

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STRATEGIC APPROACHES FOR SUSTAINABLE UTILIZATION OF RENEWABLE ENERGIES IN ROMANIAN RURAL AREAS

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ABSTRACT

Nowdays social dynamics presents some interesting aspects related to rural areas. Thus, following the development of modern means of communication, some city dwellers and some economic activities choose to migrate to the rural hinterlands. Also, rural areas with tourism potential develops by establishing business offering such services. Finally, the normal development of rural areas means, in addition to modernizing agricultural practices, the emergence of industrial units, usually small or medium, processing obtained products or exploiting local traditions. All this aspects, accompanied by an obvious increase of population comfort demands, means an increase of energy consumption required by the countryside. Ways of satisfying some increased energy consumption may be national transport and distribution networks developing or promotion of local renewable sources integrated exploitation, this latest version benefiting from the sustainability virtues. Virtually, all renewable energy sources that may be targeted are operating mature technologies and required equipment are commercially available. Promoting such behaviors require the adoption of tactics that gives return, in terms of appropriate security conditions of the power supply.

This paper aims to provide an overview of the opportunities and issues related to the practice of integrated exploitation of local renewable energy sources in rural areas and to outline, but argued, tactical actions to be, according to the author, to precede the actual crossing decision in such operations.

Key words: Renewable energy sources, integrated exploitation, rural areas.

INTRODUCTION

In the whole world the energy consumption is an important component of the civilized living and even an indicator of the general level of society development. All the attempts of rational optimization of energy consumption (buildings insulation and heat recovery from the waste water and the ventilation air, promotion of industrial transportation on water and on railroad, promoting the public transportation for the population, encouraging of individual transport by bike etc.) do not have succeeded to disengage the economic and social development from the increased demand and the actual consumption of energy. Unfortunately, the continued growth of energy production is accompanied by deterioration of the environment and sustain an argument that can be called "energy versus environment". In these circumstances, at the society level there is a growing concern for promoting the production of energy from renewable and "clean" sources. Beyond environmental caring for, this concern is supported by the forecasts regarding the prospects of exhaustion of the fossil fuel reserves and "generosity" of the environment that we want "to be his friends." Thus, with the exception of geographic areas with subarctic and arctic climate - otherwise sparsely populated and recognized as offering "harsh conditions" of life - over the whole surface of the Earth, therefore and in Romania, are available local renewable energy sources, with natural status. Such sources are the solar radiation, the heat accumulated in the atmosphere, the heat stored in water accumulations and in the waters of large rivers, the geothermal heat accumulated in the groundwater tables. Also, areas suitable for the abundant development of vegetation, which are densely populated, provides the most widespread local renewable energy resource - the biomass - which can be accessed actively (practicing energy crops) or opportunistically (valorisation of wastes from agriculture, animal husbandry, industries of wood and food processing, wastewater etc.).

Providing the most important part of the energy required by the activities from a location through the "extraction of" it from the surrounding environment, where this energy exists under latent forms more or less accessible, is an overarching objective of economic, ecological and even strategic. Thus, in economic terms, exploiting the local renewable energy sources is cost effective because, beyond the initial investment in equipment and facilities, presents low operating costs and avoids the transportation costs and even some administrative charges imposed in the centralized systems for energy distribution. Under ecological aspect, the renewable energy sources presents "sustainability" and constitutes an alternative of fossil fuels using, generally pollutant. Finally, under strategical aspect, the conduct of exploitation of the local renewable energy sources offers to the applicants a status of energy independence with proportions directly related to the intensity of exploitation.

Strategic approach to exploit local renewable energy sources conduct must comprise three directions. The first of these concerns the levels and the structure of energetic consumptions which, integrated, can describe the specific market of energy. The second direction must comprise the general renewable energy sources available in the nearby environment, defining the energy offer intended to the targeted market and the technologies and equipment available to "the extraction" of energy from the local renewable sources and its delivery to consumers, in the specific desired forms. Finally, the third direction regards to reasoned establishing of the tactics steps need to model this behavior under the banners of energy efficiency, security of supply and care for the environment.

ENERGY COMSUMPTION LEVELS AND STRUCTURE

At the current development level of Romania, especially in rural areas, the largest share in energy consumption have small or medium sized customers, whose energy demands are moderated: houses or small dwellings groups, cottages, hotels, agricultural and zoo-technical farms practicing, eventually, conditioning activities or primary processing too for a part of production, processing workshops of some products (wood, leather etc.) under handicraft regime. The energy demands of these consumers have a structure that include the electricity, mechanical energy generated by internal combustion engines on account of motor fuels and the thermal energy at low temperature (lower than 100°C) intended for heating of spaces in cold weather, preparation of domestic hot water and supplying of some technological processes organized on a small scale. Basically, in a descending order of difficulty of renewable sources obtaining from, is about liquid fuels for internal combustion engines, electricity and heat.

Internal combustion engines liquid fuels consumed in the residential field actually means, in fact, a fuel consumption for vehicles feeding. Also, in the sector of some economic activities, outside of some fuel consumptions for transportation operations, can be specified fuel consumptions for the actuation of some agricultural (tractors, selfpropelled combines etc.) or industrial (fulling mills, sawmills etc.) equipments. The problem of obtaining biofuels for the substitution of internal combustion engine fuels is marked by some difficulties which must be mentioned. Thus, at present, the main biofuel for combustion engines are the vegetable oils and the biodiesel - as substitutes for diesel oils – and the bioethanol – as substitute for gasoline. Getting them is at the expense of processing certain categories of biomass. Unfortunately, beyond the obtaining effort, that can be used to power engines manufactured for operation with fuel oil, these biofuels must be processed in order to obtain similar properties of replaced "classics" fuels. Such treatments are not, at least yet, profitable in small organizations that respond to local needs. The best evidence that biofuels obtaining for internal combustion engines supplying is an activity that has not reached the economic maturity is the fact that the current presence, at the level of a few percentage points, of biofuels in petroleum fuels delivered in distribution networks in Europe is imposed administratively and does not has economical reasons as justification. Moreover, it should be noted that, outside of some experimental and still "immature" technologies (vegetable oil production from algae cultures, bio-alcohols production from lignocellulosic materials), the biomass for the production of biofuels shall be obtained from organized cultures (oleaginous plants - for oils, cereals, pulses or fruits - for alcohols), and this aspect enroll the mentioned biofuels in the increasing disputed competition „biofuels versus food”.

Electricity is consumed, in the residential sector, to ensure "comfort and civilization" conditions (lighting, functioning of household appliances etc.). In this sector in Romania of 2006 the electricity consumption was estimated at 500 kWh / capita and estimated an increasing trend of it [1]. Four years later, in 2010 this indicator reached the value of 560 kWh / capita [2]. In these circumstances, considering the same rate of consumption growth, we can take into account a current average annual electricity consumption of 620 kWh / capita. The electricity consumption in the small-scale economic activities is more difficult to estimate, because here should be taken into account and the electrical actuation needs of

some equipments. Also, for this consumption it is difficult to find a reporting factor, of the type of average inhabitant, leading to an index of comparison.

The low temperature thermal energy is, in the residential sector, a steady necessity for domestic hot water preparation. Also, in the case of Romania, benefiting from a temperate continental climate, the low temperature thermal energy is necessary with annual periodicity, in the cold season, in order to ensure the heating of living spaces. The heating necessary can be calculated with certain accuracy, the methods of calculation being standardized [3]. For a general overview, in Romania, of the low temperature heat demand in the residential sector is satisfactory to consider the average values used by builders [4] for sizing of heating and hot water (a power of 0.05 kW heating 1 m³ of site, 50 liters of water heated from 10°C to 45°C for one person per day) and statistics on Romania [5] and its multiannual climatological regime [6]. According to the latter, Romania has about 20 million inhabitants and has 330 million square meters of living area (16.5 m² / inhabitant) and a cold season average of 165 days / year. Using the data set and considering an average height of 2.8 m for living quarters, simple calculations show that, for a person, the yearly low temperature heat amounts to 9150 kWh for heating and to 750 kWh for domestic hot water preparation. Therefore, in Romania, the yearly necessary of low temperature heat, in the residential sector, amounts to 9900 kWh / capita. The assessment of specific low temperature heat demand in the field of small-scale economic activities is more difficult, because the consumptions depends fundamentally of a number of factors with flexible manifestations such as the number of workers, the size of spaces actually used for their activities, the production structure and volume, technological approaches, etc. The problem of low temperature heat consumption for habitat conditioning come up in this field, too. Meanwhile, some manufacturing processes require technological washes claiming relatively large consumption of hot water (for example, in the primary processing of leather). Finally, numerous processes requires large amounts of low temperature heat. We can quote here, as examples, conditioning processes of vegetable products by drying (removal of acquired humidity) or dehydration (removal of partially or totally of the natural water content), the pasteurization processes in the food industry, the raw material drying in the timber industry etc.

An integrative look on those described show that the energy market which can be satisfied – partly or entirely – through the exploitation of local renewable energy sources, without the ongoing mediation of some industrial type activities, is one diffuse, which has two main components. The first of these concerns the electricity necessary evaluated, for the housing sector to 620 kWh / inhabitant x year. Must be observed that, except for isolated locations, this market may be covered, with the necessary costs, of the national electricity production and distribution system. The second component is the low temperature heat market where has been estimated, for the residential sector, a need of 9900 kWh / inhabitant x year. Regarding to the quantitative structure of this market, it is worth noting that estimates, only for the residential sector, indicating a ratio of about 1:16 between electricity and low temperature heat demands.

RENEWABLE ENERGY SOURCES AND OPERATING TECHNOLOGIES

The generic renewable energy sources available in the near environment, that define the energy supply for the market just examined, are solar radiation, wind, flowing water, geothermal heat, heat accumulated in the environment and biomass.

The Sun sends toward the Earth a huge amounts of energy in the form of solar radiation. This energy reaches the Earth's surface in the "Day" section of the diurnal cycle with intensities related to geographical position, season and weather condition in the impact area (the permeability of atmosphere to solar radiation). Of the same parameters depends and the spectral structure of solar radiation and, in terms of energy, we are interested only in the visible spectrum sharing (photovoltaic valorisable, by converting to electricity) and thermal spectrum (valorisable in form of heat captured). For the heat capture and transfer from the solar radiation are commercially available various solutions consisting of boards and systems with high yields. In addition, for photovoltaic conversion of solar radiation, are commercially available panels that lead to specific power efficiency of 0.20 ... 0.25 kW / m² and the operating life of 20 ... 25 years, along with the equipment to store captured energy and delivered them to the "classic" grid parameters.

The wind is a source of energy because the kinetic energy of moving air masses. Exploitable wind potential is a "given the place" and depends on some geographical features of the area which is considered the place, but does not excels in stability. For the wind energy exploitation, technologies consist in "placement in the wind" of some turbines which converts its energy into mechanical energy delivered at the level of a rotating shaft. Such turbines are commercially available, in performant variants, even for powers in the range of 2 ... 10 kW, according to local operations. Of course, the above-mentioned "placement in the wind" of a such turbine is required a construction which must be taken into account.

The water flowing is accompanied by the kinetic energy of moving water masses. In a certain section of the bed flow, the energy potential of flowing water is flow rate dependent. In turn, the flow rate presents slow and small variations in amplitude dependent on the season and have quick and high amplitude variation dependent on meteorological phenomena in the region which forms the so-called basin of the respective running water. Energy available in flowing water can be captured locally – in a simple decor that provide a constant and quiet flow –by placing in the water flow of some hydraulic turbines. Although existing market for such low power equipment is more limited. Presumably, this is because the necessary arrangements to ensure a constant flow of water, even if it is simple, it is expensive and, in addition, the construction of such facilities is restricted for environmental reasons.

The reactions that occur in the earth's core is a source of heat which is transmitted by conduction to the surface. In the area described, renewable energy sources, we designate heat from the depths of the planet as "**geothermal heat**". One exploitable effect of geothermal heat, present on virtually all dry stretches of the Earth, is the thermostated status of groundwater. This can be used to heat obtaining by extraction and pumping.

The environment contains large amounts of heat – as the temperature is relatively lowered. The heat originates, in the majority, of the Sun and constitute some reservoirs of

interest in terms of energy. For example, any accumulations of water are heat reservoirs that, at the scale needs the surrounding residents, have enormous capabilities. Such accumulation can be exploited in order to obtain heat by extraction and pumping. A similar effort, allows the heat extraction and pumping from shallow Earth's crust in warm or temperate zones, from the rivers or from the atmosphere.

All the technologies involving the heat extraction from an environment and its delivery, to the desired parameters, to a user are based on the use of heat pumps. In this area, recent decades have witnessed dramatic increases in performance due to advances in refrigeration and better dominions of heat transfer processes. Accordingly, nowadays many variants and types of heat pumps are commercially available, capable to extract heat from the media of -20°C ... -25°C temperature and to deliver pertinent low temperature heat raised above.

Biomass mean "the biodegradable fraction of products, waste and residues from agriculture, including vegetable and animal substances, forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste" [8]. Biomass includes absolutely all organic matter produced by the metabolic processes of living organisms and is the most abundant renewable energy resource on the planet. Incorporated into biomass energy is released by a variety of methods, which however, in the latter, is the chemical process of combustion (exothermic oxidation chemical transformation in the presence of molecular oxygen).

The forms of biomass energy capitalization are diverse: the direct burning with thermal energy generation, pyrolysis combustion with synthesis gas generation ($\text{CO} + \text{H}_2$), the fermentation and the generation of biogas (CH_4) or bioethanol ($\text{CH}_3\text{-CH}_2\text{-OH}$), the extraction, chemical transformation or enzymatic degradation with biofuels generation.

An important aspect of biomass energy resource is that many of its generic components are wastes raising management problems. This category includes the sewage sludge, animal excretions, a huge variety of agricultural and industrial wastes.

For biomass energy recovery are many technologies available and appropriate equipment for their application to small-scale, locally. Thus, for the direct burning of biomass there are technologies and equipments for the wood waste conditioning (usually, chopping) and for the preparation of pellets and briquettes from sawdust and agricultural residues. Also, the technology for the burning of such materials are known and can be applied, with appropriate adaptation sets, even in the existing fireboxes constructed for other solid fuels. In turn, the technologies of preparation, conditioning and recovery of biogas are well mastered and available, even if you still can not speak of a market for small biogas plants. So it is with synthesis gas generators and installations for the liquid fuels extraction.

Looking at things as a whole, we can say that we have all the needed technologies to exploit local renewable energy sources, and most of the equipment required for this conduct are commercially available.

TACTICAL APPROACH OF LOCAL RENEWABLE ENERGY SOURCES EXPLOITATION

To promote, in a given location, fully integrated, the local renewable energy sources exploitation, some specific actions deployment is necessary, in order to define promotion

tactics. These actions, along with the reasons and the results thereof are shown in the following.

1. ***Inventory of affordable renewable energy sources and the legal framework of approaching.*** The reason for the initial deployment of this action is that renewable energy sources that can be harnessed manifest themselves with various potentials. Beyond simply identifying these sources, evaluating their potential to be the basis for any decision approach. Also, some sources addressing (water from rivers and lakes, water tables) are subject to rigorous supervision for environmental protection. Thus, in some protected areas, legislation may prohibit some sources approach and some operating practices of some resources - waste can be legally supported.

The results of this action is in the list of affordable renewable energy sources and their potential, accompanied by limitations or legal support for the operation.

2. ***Inventory and quantitative assessment of energy consumptions possible to satisfy, partially or totally, in terms of economic profitability with energy obtained from local renewable sources.*** This action is required because energy needs at home and in local processing and conditioning processes in agriculture, food industry and small crafts market is a diffuse and uneven, and forms of energy reclaimed in this market and the quantities needed for each form should be estimated in order to allow efficient modeling of the activities they cover.

The result of this action is the actual knowledge of the market size and structure that addresses energy product of exploitation.

3. ***Elaboration of technological schemes for the exploitation of targeted renewable energy sources.*** This action is required by the fact that technological schemes adopted, even if they are well known and mature, must be simple and able to operate in integrated mode. In addition, some resources may exist competing technological schemes with different tracks and different outcomes (e.g. agricultural residues can be pelletized or briquetted and burned, or be included in the substrate for biogas production). Such variants must be known in the structuring process of the conduct of exploitation.

The result of this action is in the technical specifications for achieving operation.

4. ***Risk analyzes on the security of obtaining of energy for all variations of renewable source - specific technology of exploitation targeted and establishing the redundancy schemes to secure the supply with the energy forms for which is betting on local renewable sources.*** This action has several motivations. The first of these is the fact that local renewable energy approach presents strategic issues SWOT analyzable and risk aspects of these analyzes must be aggregated to give a picture of the risks to security of supply in an integrated operation of several sources. A second motivation is the fact that the risks materialized in the operation of a renewable energy can be offset by other sources in the integrated operating system and the possibilities for substitution should be highlighted. Also, must be defined the limit situations in which the power calls to external systems.

The results of this action are essential for organizing integrated exploitation of targeted renewable energy sources and delivered user satisfaction. Thus, on the one hand, to establish possible refill ways from a variety of sources allow the operation of the

technical set-up included in order to obtain maximum safety in the supply of energy. On the other hand, the identification of critical situations where energy supplies are affected and their communicated to the beneficiaries will enable them to establish a realistic, possible need to access external power sources of system operating renewable energy.

Following the tactical steps described are able to make sure that the establishment of facilities for integrated operation of local renewable energy sources is market useful and economically viable.

CONCLUSIONS

The above is seeking a comprehensive overview of issues related to the exploitation of local renewable energy sources. Placed equally under the banners of energy needs and environment protection, this work is, in the author opinion, insufficiently promoted and supported by concerted research for completed application solutions.

Meanwhile, highlights often overlooked aspects when talking about this conduct, such as dominant share of the need for low temperature thermal energy in the total energy market or decontaminated effect of the use of biomass categories.

Finally, are briefly presented and discussed the actions that make tactical approach and, conducted before the establishment of proper arrangements, are such as to ensure its energy capability and legality, outlet, so economic efficiency, technical performance and safety in the delivery of cheap and "clean" energy. These actions require, for detailing, research efforts because, for example, with the exception of solar radiation, for which statistical data can be accessed, investigating a location in terms of "energy capacity" requires, for objectivity and uniformity, procedural actions. Also, security of energy supply may benefit from general redundancy scheme offered as research results.

It can be appreciated that providing such a solution would allow an extension, in time, to practice exploitation of local renewable energy sources, with undeniable economic, comfort and environmental benefits.

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RELATIONSHIP BETWEEN CUTTER INCLINATION AND CUTTING FORCE FOR THE STALKS OF *SALIX* *VIMINALIS* VAR. *ENERGO*

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SUMMARY

*The paper presents the results of study regarding influences of cutter inclination on the cutting force in the case of the stems (rods) of energetic willow (*Salix Viminalis* var. *Energo*). An original research method is proposed, by the means of original equipment, designed and manufactured in the laboratories of “POLITEHNICA” University in Timisoara. The experiments were made with Inger variety at controlled moisture content, 0.025 m diameter of the rods, and a special cutting device integrated in a testing system for strength of materials (Zwick/Roell Z005), which insures cutting speed constant at $0,001667 \text{ m}\cdot\text{s}^{-1}$. Four cutter inclination levels were tested (0, 10, 20, and 30, [sexagesimal degree]). In the same time, the cutting surface quality was observed and the moisture content was controlled. The results from experiments were analyzed for determine the relationship between cutting force and cutter inclination, and, also optimal parameters. The maximum cutting force was used to drive pneumatic system design for the knife of cutting module integrated in complex equipment for sorting and packaging SRC rods in nurseries.*

Key words: SRC, willow, nurseries, cutting force, cutter inclination

INTRODUCTION

Actually, environmental demands, approached in complex dimensions regarding the necessity for find new ways of producing energy from alternative energy resources and for replace classics fuels, environmental maintenance, both with involvement on human health, records high demands for technical, economical, social and cultural aspects.

A lot of strategies and official documents at global and EU level, analyzes and give recommendations and important targets, also possibilities, for the use biomass and SRC cultures, including willow production (EU Road Map 2050 established RES share target in the Reference scenario to reach 24% in 2030 and over 25% in 2050) [10].

Particularly, each country try to develop own strategies and reach own results, involving in high degrees natural and environmental existed resources, RDI, politics, funding, education and culture.

For example, researches and analyzes show for Germany, after considering all ecological, ethical, political and technical restrictions, as well as future climate predictions, that 5,7% (680 000 ha) of cropland and 33% (1,5 Mio. Ha) of grassland can be classified as suitable for biomass production with fast-growing tree species in SRC, which produced an average yield of more than 14 tons of dry matter per hectare per year [1].

In different countries (e.g. Czech Republic [6], Slovakia [2]), it is important, in the same time, to keep the food security and to optimize the ratio between the use of the land for food and for biomass, that involve the use of modeling biomass potential under different scenarios of agricultural land utilization, which represent strategies of national food security.

Recently, biomass, including willow, became feedstock with enormous potential for chemical industry, for a large number of chemical components and manufactured products, on industrial scale, in a profitable way. It was demonstrated that willow biomass has good thermo physical compositions, and contains only small amounts of undesirable components (ash, sulphure, chlorine). Also, the content and yield of cellulose and hemicelluloses (for UWM 006, UWM 043 clones of *Salix viminalis* L), made them highly useful for an integrated multi-product biorefinery, based on lignocellulosic raw material [3], e.g. using ethylene produced from biomass, rather than from the processing of crude oil, in the production of polyethylene terephthalate (PET) [5].

Simultaneously, in different countries, specialists take care of benefit-cost analysis of hybrid willow crop production on agricultural land [4], by developing different methods both financial and mathematical [7].

Those demonstrate the increased interest for willow as SRC, and impose the development of new and special agricultural technologies, which integrates machinery, technologies and social rural activities and different approach by general and special methods [8].

Actually, the cultivation technology for SRC (willow and poplar), supposes the use of SRC rods (from 1,2 m to 2,4 m long and diameter between (0,007 ÷ 0,025) m), for feeding planting machines, which are developed, and plant willow cuttings [11].

Result the necessity to concept, design and develop agricultural machinery for harvest and conditioning SRC stems (rods) in SRC nurseries, ready-to-use for planting machines.

The overall objective of the investigation was to propose an original method for analyzing the behavior of energetic willow stems (rods) while cutting in nurseries for contribute finally at developing, build and test a system-application for practical use, based on researches about the behavior of willow rods during their preparing in nurseries for use its in planting machines.

MATERIAL, METHOD AND EQUIPMENT

Respecting the usual conditions for quality, imposed by beneficiary (users of step planting machines), the method must insure the possibility for study the influences on cutter inclination on the cutting force.

In figure 1 is presented the research method.

Based on it were selected four levels for cutter inclination, value at “zero” (position of cutter when longitude axis become rectangular with displacement axis), 10, 20 and 30 sexagesimal degrees.

RESEARCHES METHOD FOR ANALYZING THE RELATIONSHIP BETWEEN CUTTER ANGLE AND CUTTING FORCE

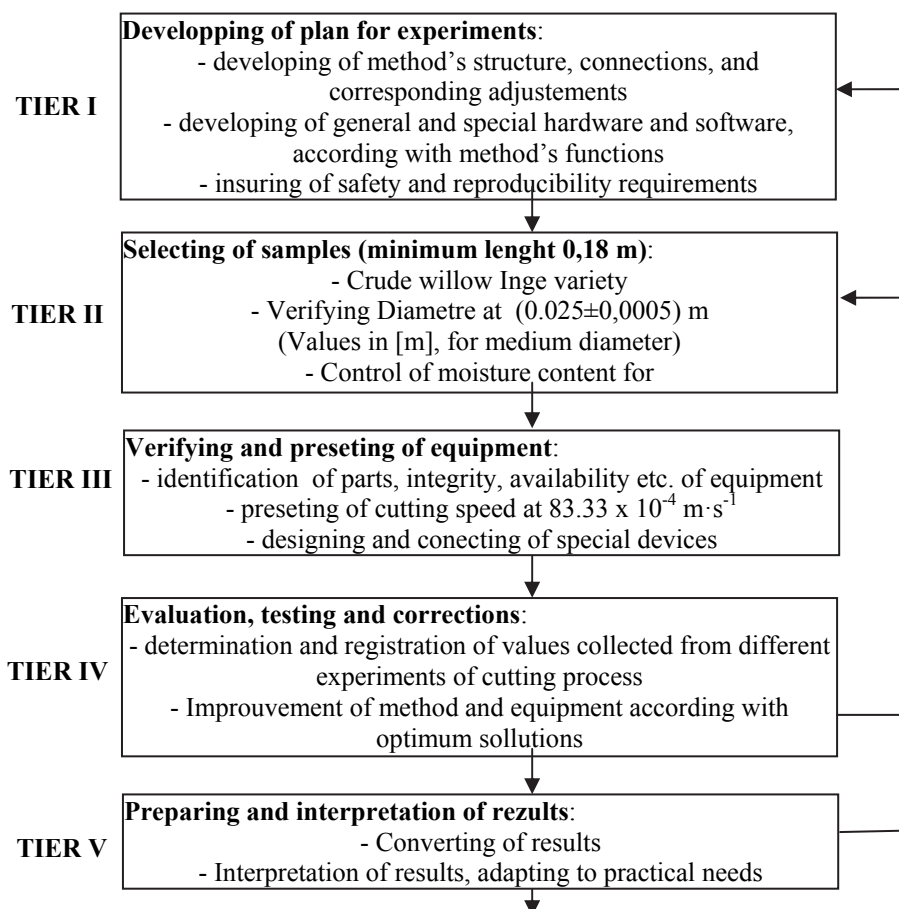


Figure 1 Steps of the process for developing of the method

The experiments were made with Inger variety at controlled moisture (the same value of moisture measured at $33 \pm 0,3$ % using gravimetric determination of moisture by PARTNER WPS 30S), rods at $0.025 \pm 0,0005$ m diameter, and a special cutting device integrated in a testing system for strength of materials (Zwick/Roell Z005), which insures cutting speed constant at $0,001667 \text{ m} \cdot \text{s}^{-1}$ (figure 2) [9]. The equipment insures data acquisition rate for the test control measurement and control electronics at 320 kHz, and test speeds between $0.0005 \div 10000 \text{ m}^3/\text{min}$, with independent speed of test load and possibility for control, as required, for position, force or strain control.

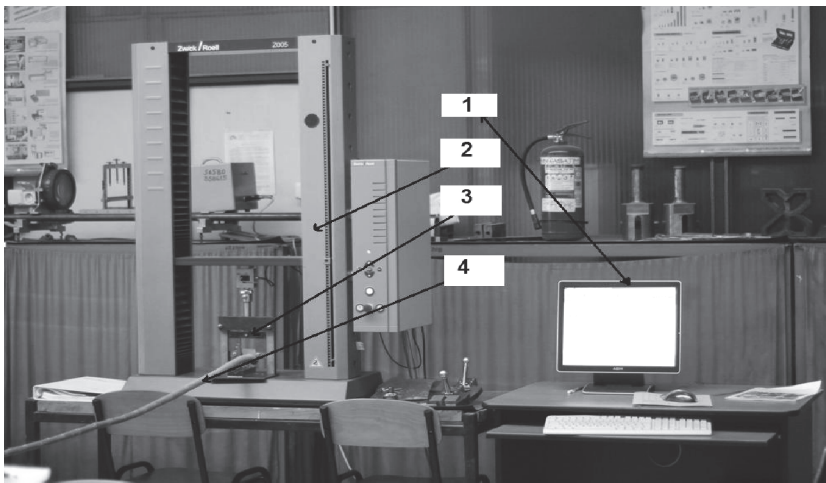


Figure 2 Experimental stand source [9]; 1 – Unit for recording and processing of the experimental data, 2- Zwick/Roell Z005 static material testing machine, 3 – SRC's cutting device, 4 – Energetic willow sample

The SRC (Short Rotation Coppices), cutting devices (position 3 in figure 2 and detailed in picture 1), permits adjustment of cutter inclination for 4 positions during experiments.

RESULTS AND DISCUSSION

Results obtained for cutting force at different cutter inclinations are presented in table 1, each registration presenting the media of results for 4 samples.

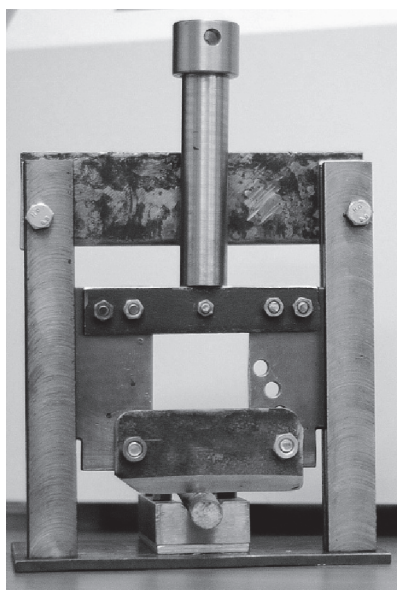
In table 1 D_n represents nominal diameter and D_m average diameter ($D_m = (D1 + D2)/2$)

In table 1, symbol D1 represents the minimum value of measured diameter and D2 represents the maximum value of the diameter (for each sample measured on orthogonal direction).

In the same time were analyzed the quality of cutted surface (Picture 2 present the aspect of cutted surface for one of the sample no 2), and it was constated not visible differences between the samples.

Table 1 Results obtained for study of dependence between cutting force, F , and cutter angle, α , for 0,025 m stem's diameter and cutting speed at $0,001667 \text{ m}\cdot\text{s}^{-1}$

Sample Nr.	D1 [mm]	D2 [mm]	D_m/D_n [mm]	α_i (Cutter Angle) [°]	F (Cutting force) [N]	Obs.
1	24,27	25,6	24,935 / 25	0	1677,9	
2	24,54	25,51	25,025 / 25	10	1536,7	
3	24,84	25,11	24,795 / 25	20	1600	
4	24,65	25,55	25,1 / 25	30	1624,5	

**Picture 1** Cutter Device**Picture 2** Cuttings from Sample no 2

Because it was impossible to insure the same measured diameters of samples (with precision at 10^{-5} m), the results were adjusted supposing a linear relationship between cutting force and sample surface.

It was introduced the coefficient for correcting cutting force, Ccf:

$$Ccf = (D_m^2 - D_n^2)/D_n^2, \quad (1)$$

The values for corrected cutting force F_c , was calculated by the relation:

$$F_c = F - Ccf * F, \quad (2)$$

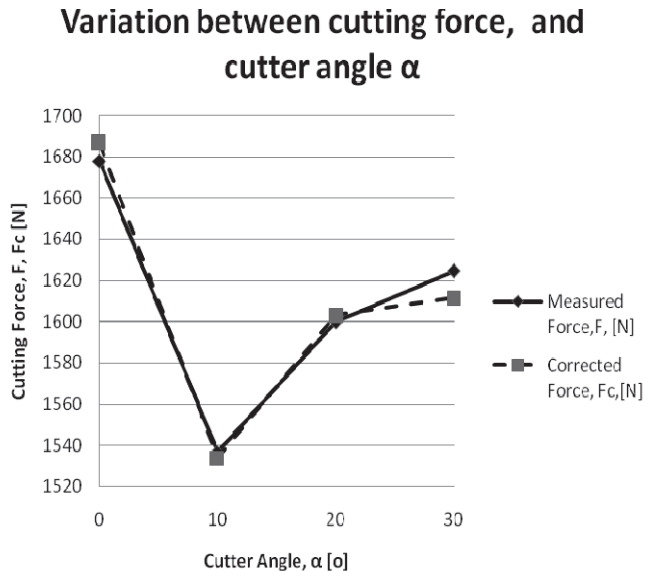
The values of coefficient for correcting cutting force, Ccf, will be considered as algebraically values ($\pm$), it means resulted positive and negative values.

The new processed values are presented in table 2.

Based on the results presented in table 2 it has been accomplished the graphical representation of the dependence between cutting force and cutting angle – both for measured values and for corrected values, as it is shown in graphic, picture 3, on the same chart.

For increasing the accuracy of graphic it was considered the values of cutting force more than 1520 N.

The results were processed, by the help of the statistically software package from Microsoft EXCEL 2007.



Picture 3 Dependence between cutting force and cutter angle

Table 2 Results obtained after correction of Cutting force values

Sample Nr.	Dn-Dm (Absolute deviation of diameter) [mm]	Ccf, (Coefficient for correcting cutting force) [-]	α_i (Cutter Angle) [°]	F (Cutting force) [N]	Fc, (Corrected force) [N]	Obs.
1	-0,065	-0,00519	0	1677,9	1686,614	
2	0,025	0,002001	10	1536,7	1533,625	
3	-0,025	-0,002	20	1600	1603,198	
4	0,1	0,008016	30	1624,5	1611,478	

After such analysis results the optimum values for cutter angle between $10\div12^0$, corresponding to the minimum value of cutting efforts. Both values for cutting force converge at optimum value and differences increase after being away from the optimal point.

CONCLUSIONS

This paper use a method for analysis of cutting process, for obtaining the optimum value of cutter angle using as optimization criteria the minimizing of cutting force. The obtained results could be used in designing of SRC stems cutting machines.

The obtained results, confirm an optimum value for cutter angle between $10\div12^0$, corresponding to a minimum value of cutting force. The position of minimum point relatively depends also on cutting speed and stem diameter, but the influences are not significant. For global analyze it will be necessary to use a multi-factorial and multi-criteria analysis, together with examination of cutting surface quality.

ACKNOWLEDGEMENT

This work was partially supported by the project „ROD PICKER - Automatic harvesting system for SRC nurseries”, financed by Research Executive Agency – Research for SMEs, Grant Agreement N°: 315416.

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DAYLIGHT ANALYSIS INSIDE PHOTOVOLTAIC GREENHOUSES

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SUMMARY

During the last years, European government remuneration policies promoted the realisation of photovoltaic systems integrated with the structures instead of on ground PV plants. In this context, in rural areas, greenhouses covered with PV modules have been developed. In order to interdict the building of greenhouses with an amount of opaque panels on covering not coherent with the plant production, local laws assigned a threshold value- usually between 25% and 50%- of the projection on the soil of the roof. These ranges seem not to be based on scientific evaluation about the agricultural performances required to the building but only on empirical assessments. Purpose of this paper is to contribute to better understand the effect of different configurations of PV panels on the covering of a monospan duo-pitched roof greenhouse in terms of shading effect and energy efficiency during different periods of the year. At this aim, day lighting analysis was performed by means of the software Autodesk® Ecotect® Analysis on greenhouse model with different covering ratio of polycrystalline photovoltaic panels on the roof. Daylight refers to the level of diffuse natural light coming from the whole sky dome or reflected off nearby surfaces to provide illumination for internal spaces within a building. Daylight Factor (DF) is defined as the ratio of the illuminance at a particular point within an enclosure to the simultaneous unobstructed outdoor illuminance under the same sky conditions, expressed as a percentage. The covering ratio (CR) is defined as the ratio, expressed in percent, between the projection on the ground of the surface of the PV panels installed on the roof and the surface of the projection on the ground of the whole roof. Daylight factor was calculated on an horizontal plane at 50cm and 150cm and 250cm from the ground in three PV greenhouses with CR=0%, CR=30% and CR=50%.

Key words: photovoltaic greenhouse, daylight, shading, illuminance

INTRODUCTION

Photovoltaic (PV) installations are quickly increasing in Europe and in Italy during last ten years. The energetic production from PV panels increased in Europe from almost 1GW in 2004 to 88GW in 2013, in the same period in Italy it passed from almost 0.1GW to 18GW (EPIA, 2014). The expansion of the PV sector- and more in general of the renewable sources sector- is due mainly to the advantageous remuneration policies available in various Countries (Sarasa-Maestro *et al.*, 2013; Badcock and Lenzen, 2010). Over the last years, in Italy, an exponential growth of PV industry, involving also the primary sector through the realization of PV systems on ground or buildings has been registered (Tudisca *et al.*, 2013). In rural landscapes, due to the consumption of land and to the environmental and biodiversity impacts involved by on ground PV plants (Beylot *et al.*, 2011, Taylor, 2014), government remuneration policies promoted the realization of integrated PV systems with the structures instead of on ground PV plants (GSE, 2013). In this context, greenhouses covered with PV modules have been developed during last years. In 2012 almost the 6% of energy produced by PV panels in Italy (16420 MW) were installed on greenhouses and shelters (GSE, 2013). The main challenge for these mixed systems is to gain higher productiveness with respect to the quality and to obtain a lower impact on environment than both systems implemented in an independent area (Poncet *et al.*, 2012). On the one hand the placement of PV modules on greenhouse takes advantage from the large surface available and avoids the heavy debate on the destination of land use because, unlike the ground systems, it does not subtract area for the cultivation of agricultural products for very long periods (almost thirty years) and it does not compromise the soil fertility (Vieri, 2012), moreover, in same period of the year- especially in Mediterranean region- shading systems are required and the activities are suspended during the summer (Marucci *et al.*, 2013). On the other hand, the area of PV modules will intercept the Photosynthetically Active Radiation (PAR) necessary for crop production and- except for specific requirements such shading systems or mushroom farms- it is in contrast with the main function of the greenhouse which is to optimize solar radiation transmission under controlled conditions, to improve the growing environment (EN13031-01, 2001; Vox *et al.* 2010). It is strategic to find a balance between two opposite needs: reduce the shading effect in order to allow as much as possible the PAR component entering into the greenhouse (Schettini *et al.*, 2011) and improve the energy production which is proportional to the opaque surface of the panels (Vox *et al.*, 2008). The greenhouse design optimization including photovoltaic panels, the development of more transparent solar panels (Yano *et al.*, 2014), and the selection of plants adapted to this particular system of production represent three technological research areas that shall be developed in the near future (Poncet *et al.* 2012).

In order to interdict the building of greenhouses with an amount of opaque panels on covering not coherent with the plant production, local laws assign a threshold value- usually the 25-50% of the projection on the soil of the roof. These ranges seem not to be based on scientific evaluation about the agricultural performances required to the building but only on empirical assessments. Purpose of this paper is to contribute to better understand the effect of different configurations of PV panels on the covering of a monospan duo-pitched roof greenhouse in terms of shading effect.

MATERIAL AND METHODS

Daylighting and insolation analysis inside different models of photovoltaic greenhouses were performed by means of the software Autodesk® Ecotect® Analysis (Autodesk, 2011).

Greenhouse models

A commercial duo-pitched roof steel glasshouse was used in simulations: span $s=10.00\text{m}$, length $l=32.00\text{m}$, distance between frames $d=3.20\text{m}$; height of the gutter $h_g=3.00\text{m}$, height of the ridge $h_r=5.00\text{m}$, roof slope 22° . Supporting steel elements were designed by means of structural code EN13031-1, hypothesising Rome- coordinates 41.8°N , 12.6°E - as building site location: column and beams steel rectangular pipes $40\times100\times4\text{mm}$, secondary elements steel circular pipes $f=33\text{mm}$ $t=2\text{mm}$ (Figure 1). In calculations, a minimum working life of 30 years was assumed. The glasshouse was E-W oriented and PV panels were settled on southern pitched roof. Polycrystalline silicon PV panels $1.00\times1.60\text{m}$, were considered in calculations. For the purpose of Ecotect Analysis was assumed: glass transmissivity $\square_g=0.95$, internal surface of PV panels made in plastic with an high reflective color (white) assuming reflectivity $\square_p=0.81$, concrete floor with reflectivity $\square_f=0.55$. Moreover, it was assumed a reduction of transmissivity of 90% taking into account the effect of accumulation of dirty on the surface. A grid- 14 rows per 44 columns- of points within the model at which light, solar insolation, can be calculated and displayed was considered in the model.

Different PV panels covering ratio (CR) were considered: greenhouse “A” (G- A) was the control model without PV panels on the roof and $\text{CR}=0\%$; PV greenhouse “B” (PVG- B) with $\text{CR}=30\%$, PV greenhouse “C” (PVG- C) with $\text{CR}=50\%$ (Figure 2). The covering ratio is defined as the ratio, expressed in percent, between the projection on the ground of the surface of the PV panels installed on the roof and the surface of the projection on the ground of the whole roof.

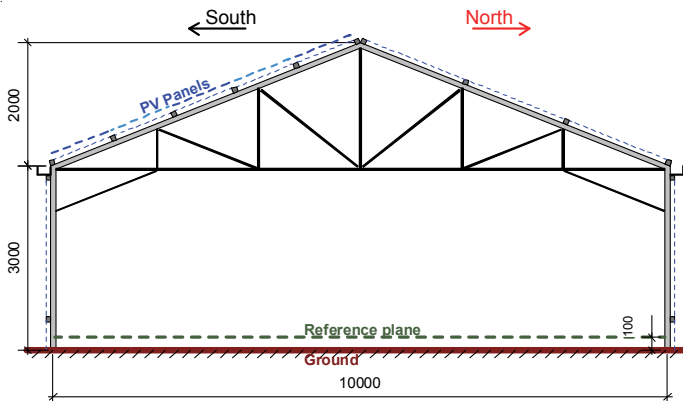


Figure 1 Main frame section of greenhouse models, measures in millimeters.

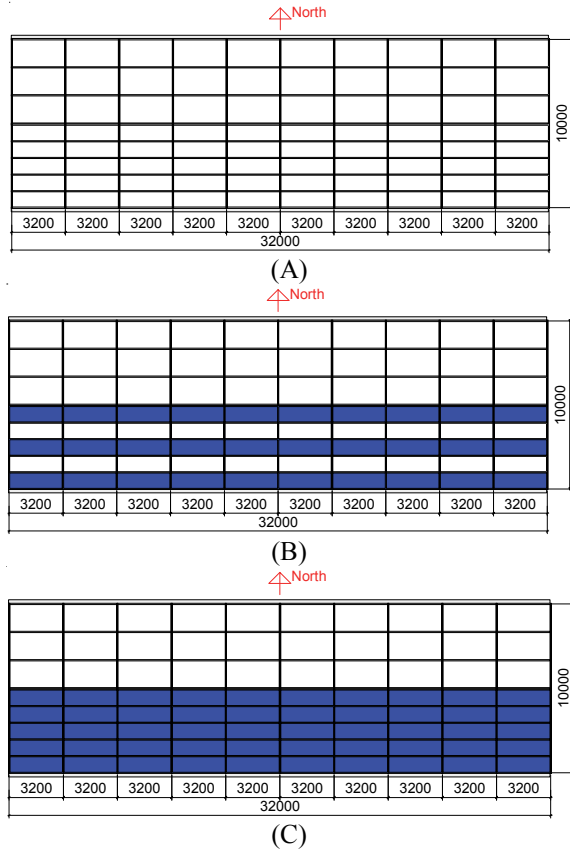


Figure 2 Covering layout of tested models with different covering ratio (CR): G- A (A); PVG- B (B); PVG- C (C). In blue, PV panels on coverings.

Daylight refers to the level of diffuse natural light coming from the whole sky dome or reflected off nearby surfaces to provide illumination for internal spaces within a building. While the main source of natural light is the Sun itself, atmospheric scattering and reflection of clouds means that the entire sky also emits light. For the purposes of day lighting design, the sky is considered as a large hemispherical surface, or dome, completely surrounding each building or space. Daylight Factor (DF) is defined as the ratio of the illuminance at a particular point within an enclosure to the simultaneous unobstructed outdoor illuminance under the same sky conditions, expressed as a percentage. Illuminance (lux) is the total luminous flux incident on a surface, per unit area. The position of the Sun in the sky varies continuously, since it is dependent on the geographical location of the site (latitude and longitude) on the time of the day and the period of the year. Sunlight is also subject to significant changes due to sky conditions (e.g., clouds), obstructions, levels of pollution, etc. The distribution of daylight from the sky dome depends on weather conditions. Clear skies tend to be brighter in the proximity of the horizon, while overcast

skies have higher luminance values at the zenith. To account for this, basing on the analysis of climate statistics, the Commission International de l'Eclairage (CIE) has defined a series of 'sky models' accounting for different luminance distribution: clear sky; intermediate sky; isotropic sky; overcast sky (CIE, 1996). Ecotect assumes CIE "Overcast sky model" day in which the majority of light comes from the zenith of the sky (up to three times more than at the horizon) (Autodesk, 2011). The model is independent of time due to the fact that the variation is only with altitude of the light source over the sky dome. Thus the Daylight Factor in a space will not vary with orientation as there is no Sun visible in the sky, it is assumed to be all diffuse light. The "Design Sky" is given as an illuminance level that is exceeded 85% of the time during the hours of 9am to 5pm throughout the working year. The Design Sky value depends only by the latitude of the site (Tregenza and Waters, 1983). Using this value, it is possible to convert a Daylight Factor into an illuminance level by simply multiplying the two. Thus- for instance- a point with a daylight factor of 10% at a location with a "Design Sky" value of 5000 lux will likely have an illuminance level of at least 500 Lux 85% of the time (Autodesk, 2011).

RESULTS AND DISCUSSION

Inside greenhouses models, DF were gathered on the planes parallel to the floor at a distance of 50cm, 150cm and 250cm from the ground (Figures 3/11). In G-A is evident the shading effect of the structures of the main entrance of the greenhouse on the eastern wall (Figure 3).

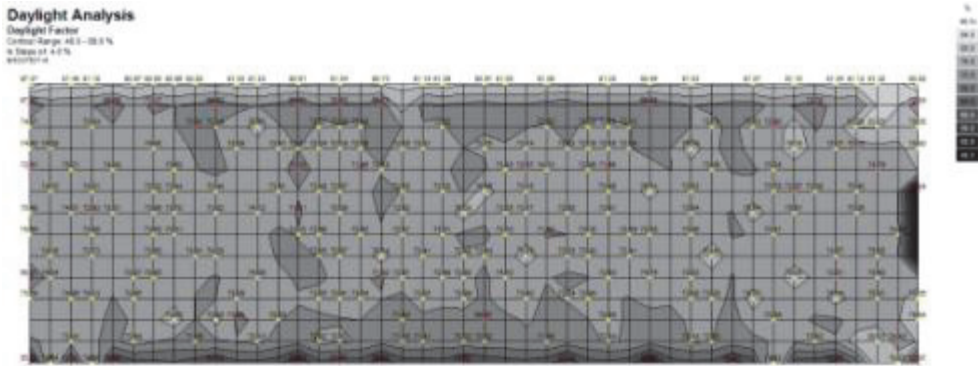


Figure 3 G-A (CR=0%)- Daylight Factor (%) calculated on a plane at 50cm from the ground. Average value 72.67%, Maximum 81.48%, Minimum 52.45%. ^ North

The average value of DF is almost constant with the height of the greenhouse passing for G-A from 72.67% at 50cm from the ground (Figure 3) to 72.45% at 150cm (Figure 6) and 72.23% at 250cm (Figure 9). A similar behavior for PV-B- 56.45% at 50cm from the ground (Figure 4) to 55.27% at 150cm (Figure 7) and 54.10% at 250cm (Figure 10) and for PV-C- 47.26% at 50cm from the ground (Figure 5) to 45.69% at 150cm (Figure 8) and 44.11% at 250cm (Figure 10). Results show an inversely proportional correlation between the DF average value and the CR.

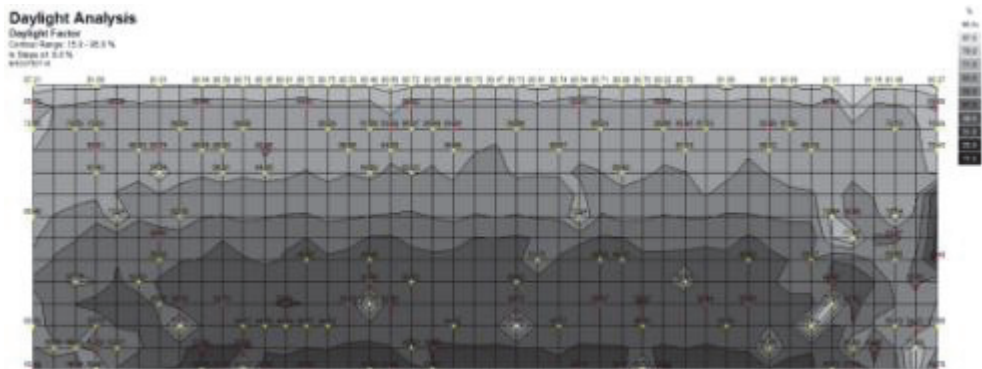


Figure 4 PV-B (CR=30%)- Daylight Factor (%) calculated on a plane at 50cm from the ground. Average value 56.45%, Maximum 81.59%, Minimum 32.20%. ^ North

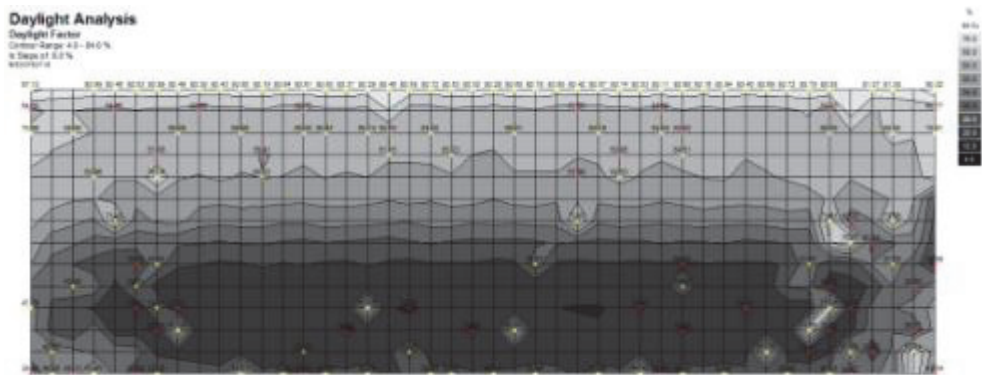


Figure 5 PV-C (CR=50%)- Daylight Factor (%) calculated on a plane at 50cm from the ground. Average value 47.26%, Maximum 81.39%, Minimum 19.90%. ^ North

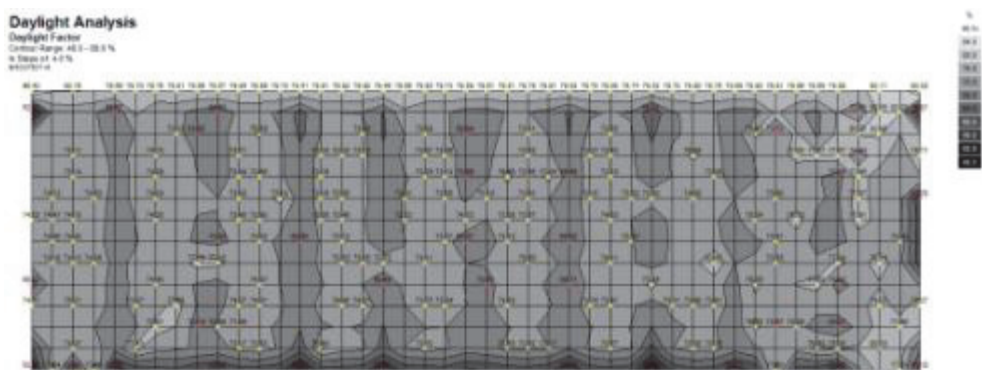
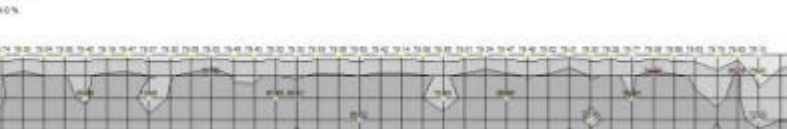


Figure 6 G-A (CR=0%)- Daylight Factor (%) calculated on a plane at 150cm from the ground. Average value 72.45%, Maximum 80.16%, Minimum 51.58%. ^ North

Daylight Analysis
Daylight Factor
Colour Range 4.0 - 90.0 %
0 Steps of 5.0 %
000000.0



The image shows a 3D model of a building's interior and exterior, overlaid with a grid. The model is rendered in a dark, semi-transparent style, allowing the grid to be seen through it. The grid is composed of a series of horizontal and vertical lines, creating a mesh-like structure. The color of the grid lines varies, with some lines appearing in shades of yellow, orange, and red, while others are in shades of blue and green. This color variation likely represents different levels of daylight intensity or exposure. The building's structure is visible through the grid, showing various rooms and architectural features. The overall image has a technical, analytical feel, typical of architectural software outputs.

Daylight Analysis

Daylight Factor
Color Range: 0.0 - 100.0 %
0 Steps of 4.0 %
0.000000

The visualization shows a grid of numerical values representing the daylight factor across a building facade. The values range from 0.00 to 100.00, with higher values indicating better daylight penetration. The visualization is titled "Daylight Analysis" and includes a legend for "Daylight Factor" and "Color Range".

709

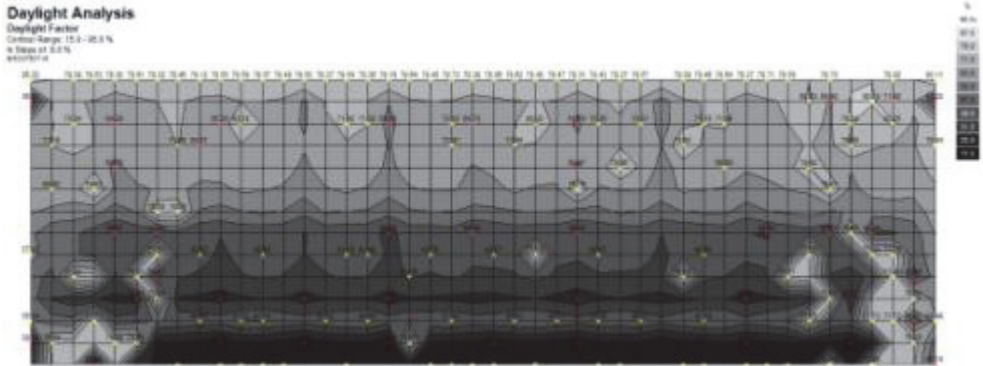


Figure 10 PV-B (CR=30%)- Daylight Factor (%) calculated on a plane at 250cm from the ground. Average value 54.10%, Maximum 78.92%, Minimum 16.34%. ^ North

Daylight Factor (DF) diagrams (Figures 3/11) highlight that the average value does not represent properly the light distribution inside greenhouses. Indeed, maximum DF values are almost the same in all greenhouses configurations- between 78.84% and 81.78%- and are gathered on the northern wall- not significantly affected by the presence of PV panels on the southern side of roof. On the contrary, minimum values change quickly depending on the PV configuration and the position inside the greenhouse. As it was expected the minimum values of DF are gathered on the southern side of the greenhouse proportionally to the CR factor passing, on the plane at 50cm from the ground from 52.45% in G-A, to 32.20% in PV-B and 19.90% in PV-C (Figures 3, 4 and 5). In greenhouses with the same CR the DF decreases getting closer to the covering. For instance, in PV-C, the minimum value of DF passes from 19.90% on the plane at 50cm from the ground (Figure 5), to 12.72% at 150cm (Figure 8) and 4.29% at 250cm (Figure 11).

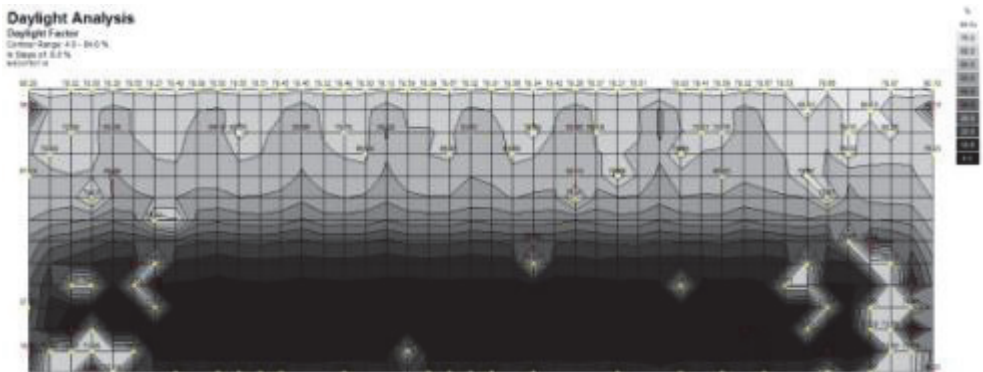


Figure 11 PV-C (CR=50%)- Daylight Factor (%) calculated on a plane at 250cm from the ground. Average value 44.11%, Maximum 78.87%, Minimum 4.29%. ^ North

CONCLUSIONS

Results show an inversely proportional correlation between the DF average value and CR. Even if DF diagrams show that the average value does not represent properly the light distribution inside greenhouses. As it was expected the minimum values of DF are gathered on the southern side of the greenhouse proportionally to the CR factor and in greenhouses with the same CR the DF decreases getting closer to the covering. The variability of shading effect is more complex to evaluate changing with the sun position, the zone inside the greenhouse and the configurations of photovoltaic panels on the roof of the structure. Results of this first study encourages to deepen in further analysis the effect of the geometric parameters of PV greenhouse and of the presence of cultivations inside and the correlation of simulation results with full scale measurements in order to calibrate the model.

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THERMAL SOLAR COLLECTORS AND ABSORPTION SYSTEM APPLIED TO GREENHOUSE COOLING

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ABSTRACT

Greenhouse microclimate depends on climatic parameters, such as solar radiation, air temperature, relative humidity and wind speed. The management of the greenhouse environment aims to ensure suitable growing condition for the crop, energy savings, and also safety condition for the workers. Solar absorption systems, exploiting renewable energy sources, can be applied for greenhouse cooling in regions with high values of solar irradiation in which evaporative systems are generally used; nevertheless evaporative systems require large quantity of water that is often a scarce natural resource in Mediterranean areas. The paper presents the technical considerations on the application of thermal solar collectors and an absorption system for cooling a greenhouse in the Mediterranean area. The simulation study was realized based on the data collected at the experimental centre of the University of Bari, Southern Italy, aiming to control the air temperature of a greenhouse having a surface of 300 m². The study aims to delineate the solar collector surface related to the greenhouse cultivated area and the potential of the system in terms of cooling capacity and energy consumption. The designed system consists of 60 m² of evacuated-tube solar collectors, a single-effect absorption chiller having a cooling capacity of 18 kW and a pilot distribution system, which provides the cooling power for the air volume surrounding the crop. The simulation showed that the delivered yearly cooling capacity for the greenhouse was 113 GJ, the required solar energy 157 GJ and the available solar energy 234 GJ.

Key words: climate control, solar cooling, renewable energy sources, lithium bromide solution

INTRODUCTION

The strong solar loads heavily affect greenhouses internal climate; furthermore greenhouses usually have low thermal insulation. The high internal temperatures may limit or prevent cultivation of crops; therefore in the warm climate areas such as the Mediterranean basin the cooling systems become necessary equipment during hot periods in order to control the internal climate and to obtain suitable environmental parameters of the greenhouses. The manipulation of climatic parameters such as solar radiation, air temperature and relative humidity, carbon dioxide concentration, can guarantee suitable growing condition for the crop and significant energy savings (Von Zabeltitz, 1999; Vox et al., 2010).

The natural and artificial ventilation is a cheap, simple method for cooling greenhouses, though it is generally not adequate for removing the excess heat during hot periods. Greenhouse cooling using conventional refrigeration or dehumidification is too expensive in terms of installation and operation costs, because the peculiar operation of a greenhouse involves removing a large quantity of heat from the internal ambient during warm periods (Davies, 2005; Kumar et al., 2009; Vox et al., 2010).

The evaporative cooling methods, such as fan-pad and fog systems, can efficiently control the internal air temperature with minimum power consumption. Nevertheless they work best in hot and semi-arid climate because their operation is based on the conversion of sensible heat into latent heat through the evaporation of water supplied to the greenhouse (Ahmed et al., 2011; Kumar et al., 2009; Jain and Tiwari, 2002). These systems can satisfy up to 80% of cooling demand of a greenhouse during arid summer conditions (Sethi and Sharma, 2007) furthermore they require large quantity of high quality water, often a scarce natural resource especially in the Mediterranean area. Alternative cooling methods rely on the use of the potential of the earth ground or of the underground aquifer water since they have a constant year round temperature; therefore their temperature in summer months results to be lower than ambient one. The earth to air heat exchanger systems (EAHES) can lower the greenhouses internal air temperature of about 0-8° C depending on the specific environment conditions of each area (Mongkon et al. 2013). The systems utilizing aquifer coupled cavity flow heat exchanger (ACCFHES) have minor costs in comparison with EAHES being deep digging of soil not required; moreover they have higher cooling performance because the aquifer water temperature has been found lower than the ground temperature during the whole year (Sethi and Sharma, 2007). The application of these composite systems involves favourable energy savings (Ghosal and Tiwari, 2006; Ghosal et al., 2004; Sharan, 2009; Ozgener and Ozgener, 2010; Yildiz et al., 2012) as compared to other conventional cooling systems.

Taking advantage of having the cooling requirements in phase with the solar energy availability, solar-powered cooling systems can be used for greenhouse sector (Vox et al., 2014). The solar cooling is a solar thermal technology that exploits the solar energy to produce cold. The electrical consumption of these systems is limited to operate a few plant components, therefore they are characterized by a considerable electricity saving, in some cases up to 95% (Desideri et al., 2009) and to a reliable reduction of the environmental impact correlated to the fossil fuel based energy use (Al-Alili et al., 2012; Ghaddar et al., 1997; Chidambaram et al., 2011). Solar cooling systems can be generally divided in: solar

photovoltaic-based electrical cooling systems; solar combined power and cooling systems; solar collector-based thermally driven cycles (Sarbu and Sebarchievici, 2013; Chidambaram et al., 2011; Hwang et al., 2008; Kalkan et al., 2012).

A solar collector-based thermally driven cycle exploits the solar energy to produce thermal energy for cooling through the thermochemical or thermo physical processes in thermally activated energy conversion systems (Hwang et al., 2008). A solar thermal collector directly converts solar energy into heat that is transferred to the heat transfer fluid in the collector; this fluid is stored in a storage tank to be utilised when necessary. Therefore the solar thermal cooling systems typically consist of solar collectors, storage tank and cooling machine connected through pipes, pumps and control unit (Sharma et al., 2011; Sarbu and Sebarchievici, 2013).

The solar thermally driven closed cycles are a typology of solar collector-based thermally driven cycles (Kalkan et al., 2012). They are classified in the adsorption cycle and the absorption cycle, and based on the sorption material: a liquid sorption for the absorption cycle and a solid sorption for the adsorption cycle (Hwang et al., 2008). The adsorption cycle solar cooling system uses the solar energy in the adsorption cycle that is a surface phenomenon based on the exploitation of the large adsorptive capacity of a solid porous surface. The operation of the adsorption cycle solar cooling system is based on two sorption chambers, an evaporator and a condenser. In the evaporator the water is vaporized under low temperature and pressure; in the first sorption chamber the water vapour is adsorbed by the solid sorbent; in the second sorption chamber takes place the regeneration of the solid sorbent by applying heat; the vapour realised is then condensed to liquid by the cooling water supplied from a cooling tower in the condenser (Sarbu and Sebarchievici, 2013). The absorption cycle solar cooling system separates a refrigerant from the refrigerant/absorbent mixture using the thermal energy obtained from solar collectors; this cooling system uses a thermal compressor. The system consists of an absorber, a desorber, a pump, an expansion valve, a generator, a regeneration, an evaporator, a storage tank and a heater. In the absorber the absorbent solution is diluted with the refrigerant creating an absorbent/refrigerant solution. This solution, pumped to a higher pressure to the generator, is heated. In the desorber, the refrigerant is separated from the solution by means of the desorption process by adding heat. The separated refrigerant is then condensed in the condenser, expanded through the expansion device, and evaporated in the evaporator in order to be again absorbed in the absorbent solution (Hwang et al., 2008; Kalkan et al., 2012). The cooling effect is based on the evaporation of the refrigerant (water) in the evaporator at very low pressure. The heat provided in excess by the solar collectors is stored in a hot water storage tank; hot water stored is used when it is necessary together with the auxiliary heater. Regarding the driving temperature of the systems, the required heat source temperature is usually in the range 60-110°C for single-effect machines; double-effect machines, having two generator stages, require heat source temperature above 130 °C (Hwang et al., 2008).

This paper presents the results of a research on the application of a solar absorption cooling system to a Mediterranean greenhouse at the experimental farm of the University of Bari, where recent researches have been carried out on the application of renewable energy sources for greenhouse heating and climate control (Scarascia Mugnozza et al., 2011, 2012; Vox et al. 2008; Russo et al., 2014). Aim of the research was to delineate the solar collector

surface related to the greenhouse cultivated area and the potential of the system in terms of cooling capacity and energy consumption. This system has a strong potential for cooling greenhouse in warm climates providing significant energy-saving and environmental protection opportunities.

MATERIALS AND METHODS

The experimental greenhouse is located in Valenzano (Bari, Italy; latitude 41° 05' N, longitude 16° 53' E). The greenhouse, made of tubular galvanized steel, is an arched roof type covered with plastic film, south-north oriented, having a covered area of 300 m² (30 m in length, 10 m in width), 4.45 m high along the ridge and 2.45 m along the gutters (Fig. 1). The greenhouse covering film is an ethylene-vinyl acetate copolymer film (EVA), with a thickness of 200 µm, characterised by a solar total transmissivity coefficient of about 85–90% in the wavelength range 300–3,000 nm. The base and the warheads (south and north-facing greenhouse surface) are polycarbonate (PC) sheets. The greenhouse is provided with a geothermal heat pump and an experimental solar photovoltaic-electrolyser-fuel cell power system with energy backup consisting of hydrogen storage. The array of photovoltaic panels has a power of 7.38 kW. The application of this power system allows reducing the dependence from fossil sources and the environmental impact associated with the operation of the greenhouse (Blanco et al., 2014).



Figure 1 The inside of the greenhouse

The task of the designed cooling system is to lower the greenhouse inside air temperature when it exceeds 30 °C in order to allow crop cultivation during warm months.

The cultivation of the plants takes place in plastic pots (1.00 m x 0.40 m x 0.40 m) with a growing substrate made of a mixture of soil and peat. The pots are equipped with an automated drip irrigation system. The greenhouse is equipped with an electronically controlled horizontal shading net (placed inside the greenhouse), four electrical fans positioned on the north-facing greenhouse surface, two air inlet louvers placed on the

south-facing greenhouse surface, two vents on the greenhouse ridge and two on the east and west sides respectively, ensuring forced and natural ventilation. The cooling distributing system consists of pipes, positioned at the crop level, through which the cooled water circulates lowering the plant temperature.

RESULTS AND DISCUSSION

The system was designed based on the climatic data measured in the area where is located the greenhouse at the experimental farm of the University of Bari. Table 1 reports the average climatic values of the site measured during 2013: maximum, minimum, mean external air temperature, external air relative humidity, solar radiation.

The system consists mainly of an evacuated tube solar thermal collectors array that provides heat to an absorption chiller that produces cooled water (Fig. 2). The plant cooling is obtained distributing the cooled water through plastic pipes, obtaining the cooling of the air nearby the plants. The electrical energy necessary for the cooling system is partially supplied by the experimental power system exploiting the hydrogen production and storage.

Table 1 Average maximum and minimum external air temperature, mean external air temperature and RH, solar radiation (2013)

		Months											
		J	F	M	A	M	J	J	A	S	O	N	D
Air temperature (°C)	maximum	13.5	13.3	17.0	23.0	26.9	29.5	32.1	32.9	28.6	24.8	18.9	14.9
	minimum	5.4	4.2	7.8	10.9	14.0	17.4	20.0	20.9	17.1	14.7	10.7	6.2
	mean	9.0	8.2	12.0	16.4	20.3	23.6	26.5	26.8	22.5	18.9	14.2	9.8
Air relative humidity (%)	average	78.6	77.5	76.5	62.3	57.4	55.4	54.0	57.4	64.7	81.5	83.7	85.4
Solar radiation on horizontal plane (kW h/m ² /month)		153	215	349	557	632	726	761	647	482	302	158	144

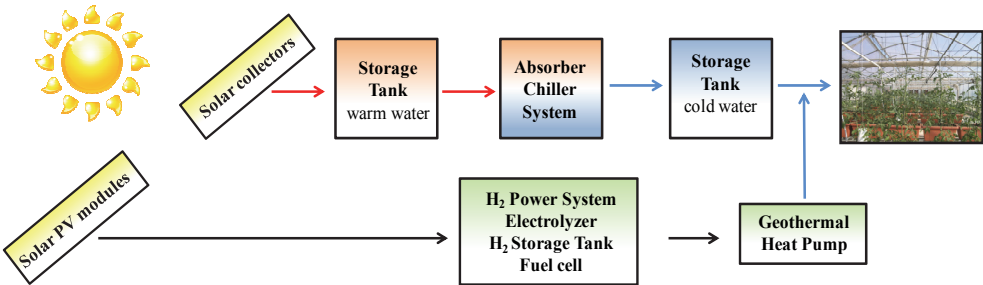


Figure 2 Functional diagram of the designed cooling system

The design of the cooling system has taken into consideration the climatic data recorded at the experimental centre and two different cooling conditions in order to evaluate the cooling energy demand necessary to guarantee suitable growing conditions for the crop. In the first condition it was supposed to cool the whole greenhouse area; then it was supposed to cool locally the growing area around the plants, placing the pots on benches with the sides equipped with cooling radiating surfaces. The cooling capacity was calculated by means of the following heat balance equation:

$$Q_C = I_r \cdot \tau_{cp} \cdot (1 - \rho) \cdot S - U \cdot S \cdot \Delta T \quad (1)$$

where: I_r is the incident solar radiation, assumed equal to 900 W m^{-2} ; τ_{cp} is the covering transmissivity, assumed equal to 0.85; ρ is the reflectance of the soil and of the shading net, assumed equal to 0.5; S is the covered area that must be cooled; U is the global heat transfer coefficient of the greenhouse, assumed equal to $10 \text{ W m}^{-2} \text{ }^\circ\text{C}^{-1}$; ΔT is the temperature values difference between the inside and outside temperature of the greenhouse, equal to $1 \text{ }^\circ\text{C}$. The area to be cooled according to the first hypothesis was assumed equal to 300 m^2 ; in the second hypothesis, considering only the growing area, it was assumed equal to 40 m^2 .

The cooling energy demand, evaluated for the two different cooling conditions was 112 kW for the first hypothesis and 18 kW for the second one, respectively. Considering the visual impact of the solar panels, the resulting surface of the solar collectors required by the system for the first hypothesis, about 350 m^2 , makes it almost inapplicable. Considering the second hypothesis, instead, the necessary capturing surface of evacuated-tube solar collectors, with a tilt angle of 30° , was equal to 60 m^2 , so that they can be placed on the ground outside. They can even be positioned inside the greenhouse in the extreme parts of the greenhouse at the level of the eaves, ensuring no shading over the cultivation area placed in the middle of the covered area and increasing their global capturing surface by 10-15 % in order to compensate the reduction of the energy passing through the covering film. The designed solution consists of:

- A water-fired single effect absorption chiller (Fig. 3-4) using a combination of water/lithium bromide as fluid for absorption cooling, having a cooling capacity of 18 kW with a heat input of 25.1 kW, an electrical consumption of 1.45 kW, a $\text{COP}_{\text{thermal}}$ of 0.70 with a supply/return cooling water of $7/12 \text{ }^\circ\text{C}$, nominally requiring an in/out temperature from the solar array of $88/80 \text{ }^\circ\text{C}$ (Fig. 5);
- A cooling tower with a heat rejection of 43 kW and an inlet/outlet cooling water temperature of $35/30 \text{ }^\circ\text{C}$;
- An hot water storage with a global capacity of 2 m^3 ;
- A cool water storage with a global capacity of 0.5 m^3 .

The described solution was studied considering the equipment available on the market. The designed solar cooling system is backed up by the geothermal heat pump, used as an auxiliary heat source, in order to integrate the system mainly at the start-up.

The data reported in Fig. 6 show as the designed system is in phase with the climatic data collected at the experimental farm; the simulation showed that the delivered yearly cooling capacity for the greenhouse was 113 GJ, the required solar energy 157 GJ and the

available solar energy, calculated for a capturing surface of 60 m² with a slope of 30°, was 234 GJ.



Figure 3 The absorption chiller

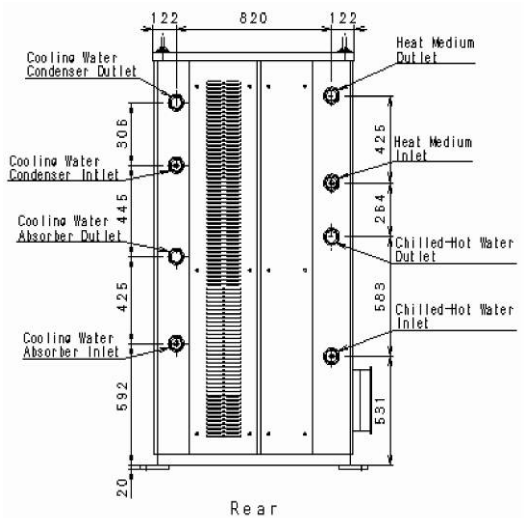


Figure 4 Inlets and outlets of the absorption chiller (Yazaky, 2014)

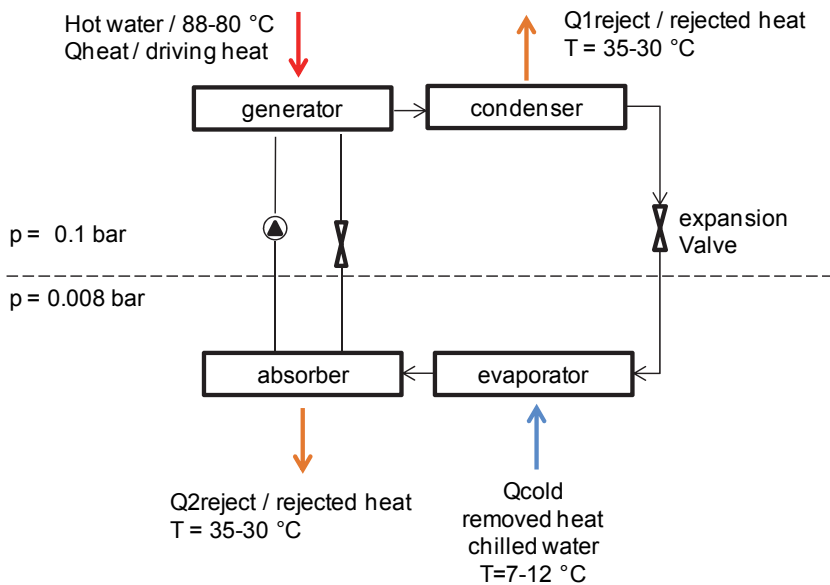


Figure 5 Basic scheme of a thermally driven cooling system

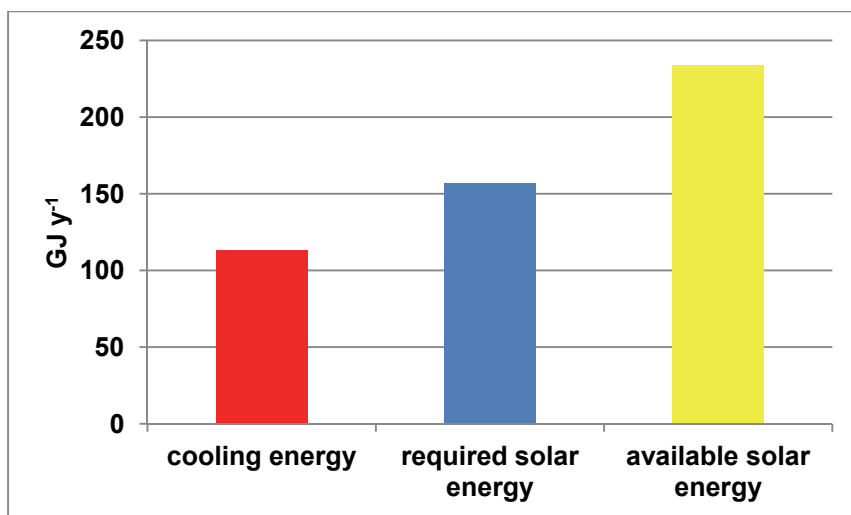


Figure 6 Cooling energy demand, required solar energy and the available solar energy

CONCLUSIONS

The application of the absorption chillers to greenhouse cooling offers the great advantage of having a system in phase with the daily solar radiation. The design has taken into consideration the improvement of the basic system introducing a high capacity hot water storage and an auxiliary heat source, the ground source heat pump, in order to get continuous operation of the generator. In consideration of the high temperature required by the absorption system, evacuated tube solar collectors, instead of flat type, have been chosen for their high efficiency. Due to the visual impact of the large capturing surface required for the solar collectors for cooling the whole greenhouse, it was supposed to apply a localised cooling system, achieving a substantial reshaping of the capturing surface; the efficiency of this method must be experimentally proven. The solar cooling systems greatly reduce the electricity consumption; furthermore they can be improved exploiting the electrical energy produced by photovoltaic systems. The system described could provide significant energy-saving opportunities for cooling greenhouses in hot climates allowing significant reduction of electricity and water consumption by exploiting the contemporaneity between the cooling requirements and the solar energy availability.

ACKNOWLEDGEMENTS

The research was carried out under the project “Diffusion of Cooling and Refreshing Technologies using the Solar Energy Resource in the Adriatic Regions (Adriacold)”, funded by the European Commission in the frame of IPA Adriatic Cross Border Cooperation Programme.

The authors shared programming and editorial work equivalently within the areas of their expertise.

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VERTICAL GREEN SYSTEMS FOR BUILDINGS CLIMATE CONTROL

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ABSTRACT

The phenomenon of urban warming, known as urban heat island, negatively influences outdoor comfort conditions and pollutants concentration and as well increases the environmental impact due to the energy demand for air conditioning. Urban warming can be attenuated by reducing the solar heat gain that increases building's temperature during the hot season. Solar heat can be mainly reduced by increasing the insulation between the exterior and interior of the building, as well as by shading the building surface from direct sun exposure. A sustainable technology for improving the energy efficiency of buildings is the use of green roofs and green walls that: allow the physical shading of the building and promote evapotranspiration in summer; increase the thermal insulation in winter. An experimental test was carried out at the University of Bari (Italy, 41 ° 05 'N, 16 ° 53 'E). Three prototypes of building vertical wall, made with perforated bricks, were designed: two vertical walls were covered with plants (one with Pandorea jasminoides variegated, the second with Rhynchospermum jasminoides) while the third wall was kept uncovered and was used as control. A system composed by a data logger and sensors was used to measure and record the following parameters: temperature of the wall surface under solar radiation and of the surface on the other side of the wall, solar radiation falling on the wall, external air temperature and wind speed. During summer 2014 the diurnal temperatures of the control surface exposed to the solar radiation were higher by about 4 °C compared to the temperatures recorded on both the vertical walls covered with Rhynchospermum jasminoides and Pandorea jasminoides variegated. The thermal wave propagated with a phase shift of about 2 hours and half.

Key words: *urban agriculture, energy savings, passive systems, urban heat island, surface temperature, solar radiation*

INTRODUCTION

Urban Heat Island (UHI) is the name given to the worldwide phenomenon of higher air temperature in urban area in comparison to the surrounding suburban and rural areas, with a difference that can be up to 5-6 °C (Rowe, 2011; Kanechi, et al, 2014; Karlessi et al., 2009; Karlessi et al., 2011; Berdahl and Bretz, 1997; Bretz and Akbari, 1997; Bretz et al., 1998; Gentle et al., 2011; Gladis and Schumann, 2011; Jo et al., 2010; Joudi et al., 2013; Li et al., 2013; Prado and Ferreira, 2005; Synnefa et al., 2006; Uemoto et al., 2010; Zinzi et al., 2012). The phenomenon of UHI occurs due to: built surfaces made with non-reflective and water-resistant construction materials, that absorb a high percentage of the incident solar radiation and emit heat; the waste heat produced from human activity such as cooling systems, industrial processes and motorized vehicular traffic; the non-circulation of air in urban canyons; the incidence and speed of the wind; the decrease of urban vegetated areas with a reduction of shades and radiation interception; the reduced ability of the emitted infrared radiation to escape in the atmosphere; the scattered and emitted radiation from atmospheric pollutants to the urban area (Santamouris, 2012). UHI influences negatively outdoor comfort conditions, pollutants concentration and as well induces excessive use of air conditioning systems with an increase of energy consumption for cooling and a raise of peak electricity demand (Karlessi et al, 2009; Karlessi et al, 2011; Jaffal et al., 2012). The phenomenon of UHI is also particularly harmful to human health, especially of the sick, elderly and children, as in the summer, when air temperatures in the city are consistently high during the 24 hours, the human organism has problem to recover overnight from extreme heat to which it was subjected during the day (Kalkstein and Davis, 1989; Petralli et al., 2006).

A sustainable technology for improving the energy efficiency of buildings in cities is the use of vegetated horizontal and vertical systems in order to reduce the energy consumption for air conditioning in summer and to increase the thermal insulation in winter (Cheng et al, 2010; Jim and Tsang, 2011; Köhler and Poll, 2010; Perini et al, 2011; Pérez et al, 2011; Berardi et al, 2014; Fernandez-Canero et al, 2013; Santamouris, 2012). Green roofs and vertical systems can be used as passive energy savings systems because they intercept solar radiation by the vegetation layer, provide thermal insulation by means of the vegetation and substrate, induce evaporative cooling by evapotranspiration from the plants and the substrate, and influence the effect of the wind on the building (Perez et al., 2011). Green roofs and vertical systems offer several benefits both on the roof/facade itself, on the building and on its surrounding urban environment. They also have social, environmental and aesthetical benefits depending on the climatic conditions of the area, on the greening technology design, on the building characteristics and on the urban context (Fioretti et al., 2010; Castleton et al., 2010; Wong et al., 2003; Perini et al., 2011; Wong et al., 2010; Berardi et al., 2014; Santamouris, 2012; Benvenuti, 2014; Rowe, 2011; Kohler, 2008; Francis and Lorimer, 2011; Fernandez-Cañero et al., 2013). The design of green roofs and walls depends on the characteristics of the buildings and on the climatic conditions of the area (Fioretti et al., 2010; Castleton et al., 2010; Spala et al., 2008; Berardi et al, 2014;

Fernandez-Cañero et al., 2013; Santamouris, 2012; IGRA, 2014; Perez et al., 2011; Perini et al., 2011; Francis and Lorimer, 2011; Jim and He, 2011; Kontoleon and Eumorfopoulou, 2010).

Castleton et al. (2010) reported a worldwide surface of 234 ha of green roofs and vertical systems. In Italy about 1000 m² of roofs are vegetated while in Germany there are about 13.5 km² of green roofs, equal to 14% of all flat roofs (Castleton et al., 2010). In the Mediterranean region, where the climate is characterized by limited water, the diffusion of green technology is limited due to a lack of knowledge of its benefits and characteristics, and by the lack of governmental incentives (Fernandez-Cañero et al., 2013). The summer drought poses a limit for plant survival in difficult condition of cultivation such as the use of reduced depth for the substrate. There is a need of research for evaluation of plant species adapted to the Mediterranean regions.

The aim of this research is to evaluate the effects of green walls on the thermal regime of a wall subjected to solar radiation. Surface temperatures and climatic data were experimentally evaluated during a test carried out at the University of Bari, in order to evaluate the reduction of the wall surface temperature by using of a vertical green wall.

MATERIALS AND METHODS

The test was carried out at the experimental farm of the University of Bari in Valenzano (Bari), Italy, having latitude 41° 05' N, longitude 16° 53' E, altitude 85 m ASL. A prototype of building vertical wall in scale was designed and it was made with perforated bricks joined with mortar. The bricks were of the following dimensions: 20 cm thick, 25 cm height and 25 cm length. They were characterised by thermal characteristics such as: thermal conductivity λ (following UNI EN 1745:2012) equal to 0.282 W m⁻¹ K⁻¹; average weight of the masonry work (including plaster) equal to 695 kg m⁻³; specific heat capacity C equal to 840 J kg⁻¹ K⁻¹.

The wall made with perforated bricks was chosen because it is commonly used as a system of vertical closure for civil construction in the Mediterranean area. Three walls facing south were made, each having a width of 1.00 m, a height equal to 1.55 m, and a thickness of 0.20 m. In order to allow the correct evaluation of the influence of the plants on the effects of incident solar radiation, the backside of each vertical wall has been insulated by means of a sealed structure. The sealed structure was made of sheets of expanded polystyrene, characterized by a thickness of 30 mm and a thermal conductivity equal to 0.037 W m⁻² K⁻¹. A blue shading net was positioned onto the structure to reduce the effect of the incident solar radiation.

Two vertical walls were covered with vigorous evergreen climbing plants, one with *Pandorea jasminoides* variegated, the second with *Rhynchospermum jasminoides*, while the third wall was kept uncovered and used as control. The plants were transplanted on June 18, 2014. The day after the transplant, in order to provide a better support for the climbing plants, a net has been placed between the plant and the wall; each net was placed about 10 cm far from the vertical wall (Figure 1).

The drip irrigation method was used for all the plants and fertilization with N: P: K 12:12:12 was performed.



Figure 1 The three walls at the experimental field of the University of Bari; the right wall is covered with *Rhynchospermum jasminoides*, the central wall with *Pandorea jasminoides* variegated and the left wall is the uncovered control.

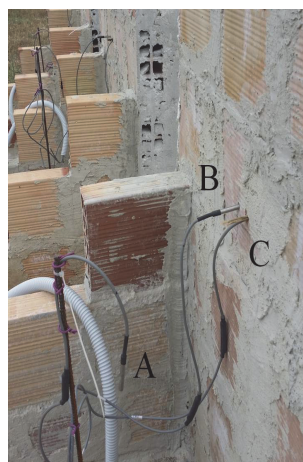


Figure 2 Location of the temperature sensors: sensor for the indoor temperature inside the volume behind each wall (A), sensor for the surface temperature of the wall on the inner side (B), sensor for the surface temperature of the external plaster exposed to the solar radiation (C).

The experimental field was equipped with a meteorological station consisting of a data logger (CR10X, Campbell, Logan, USA) and sensors for measuring several climatic parameters. The parameters measured were: the external air temperature, the solar radiation incident on the vertical surface, the speed and wind direction, the surface temperature of the wall on the inner side, the surface temperature of the external plaster exposed to the solar

radiation, and the indoor air temperature inside the sealed volume behind each wall. The data, measured with a frequency of 60 s, were averaged every 15 min and stored in the data logger.

The surface temperature of the wall on the inner side, the surface temperature of the external plaster exposed to solar radiation, and the indoor temperature inside the sealed volume behind each wall were measured using thermistors (Tecno.el s.r.l. Formello, Rome, Italy); the sensors were located as shown in Figure 2.

The solar radiation incident on the vertical surface was measured by a pyranometer (model 8-48, Eppley Laboratory, Newport, RI, USA) in the wavelength range 0.3-3 mm. External air temperature was measured during the test by using an Hygroclip-S3 sensor (Rotronic, Zurich, Switzerland), which was shielded from solar radiation. The speed and direction of the wind were measured by a Young Wind Sentry 03002 sensor (Wind Sentry Data Sheet 03002, RM Young Company 1999): the wind speed by an anemometer with small rotating vanes that produce a sinusoidal signal whose frequency is proportional to the wind speed; the wind direction by a potentiometer wind vane whose resistance is a function of the orientation vane. The measuring ranges are 0-50 m s⁻¹ for the wind speed and 0-360 ° for the wind direction.

RESULTS AND DISCUSSION

The field observations showed that the plants development was strongly influenced by the severe weather conditions recorded during the summer 2014. The two walls were sufficiently covered by vegetation from mid August 2014 even if *Pandorea jasminoides* variegated was more widespread than *Rhynchospermum jasminoides*.

From 15 to 31 August, the vegetation has started to cover the central part of the vertical wall, where the temperature sensors were located, more significantly than at the beginning of the test. Figure 3 shows the daily maximum surface temperature of the external plaster exposed to solar radiation measured during the period 15-31 August 2014: the maximum surface temperature of the control (recorded on the wall not covered with plants) was always higher during the hot hours of the day than the temperatures recorded in the same hours for the vertical walls covered with *Rhynchospermum jasminoides* and *Pandorea jasminoides* variegated.

The differences between the highest temperatures recorded for the control and for the wall covered with plants ranged from 3 to 4 °C. The presence of vegetation mitigates the quantity of solar radiation absorbed by the walls and, consequently, reduces the temperature of the plaster of the external walls covered by climbing plants respect to the wall without cover green. The differences with the control certainly will increase when the entire surface of the walls will be completely covered by vegetation.

The thermal wave, which propagates from the external wall to the internal surface of the wall, shows a time delay or time lag, which is due to the thermal mass of the materials, equal to 2 hours and half as shown in figures 4 and 5 for the wall covered with *Rhynchospermum jasminoides* and for the control wall, respectively. The time lag is the time required for a heat wave to propagate through a wall from the outer to the inner surface that is actually the time required for the heat to pass through a material.

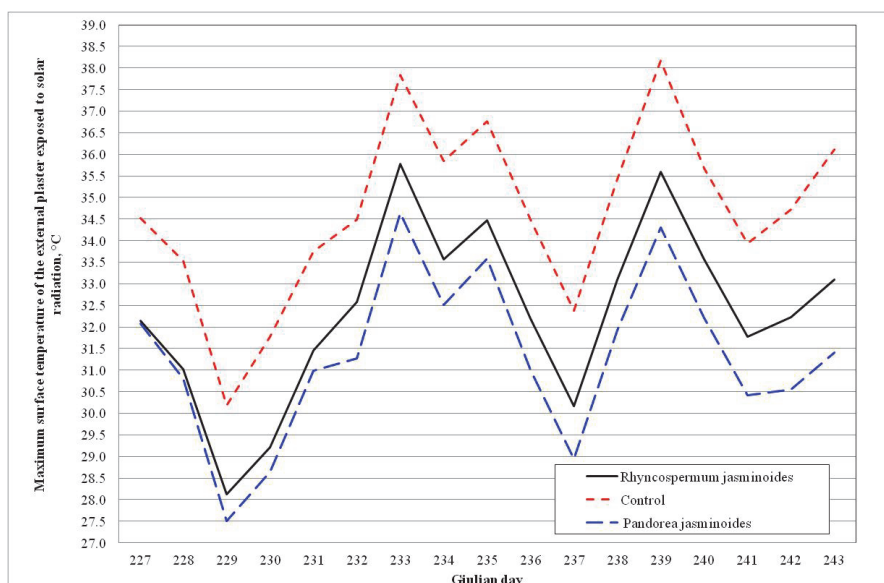


Figure 3 Daily maximum surface temperature of the external plaster of the three walls exposed to solar radiation measured during the period 15-31 August 2014.

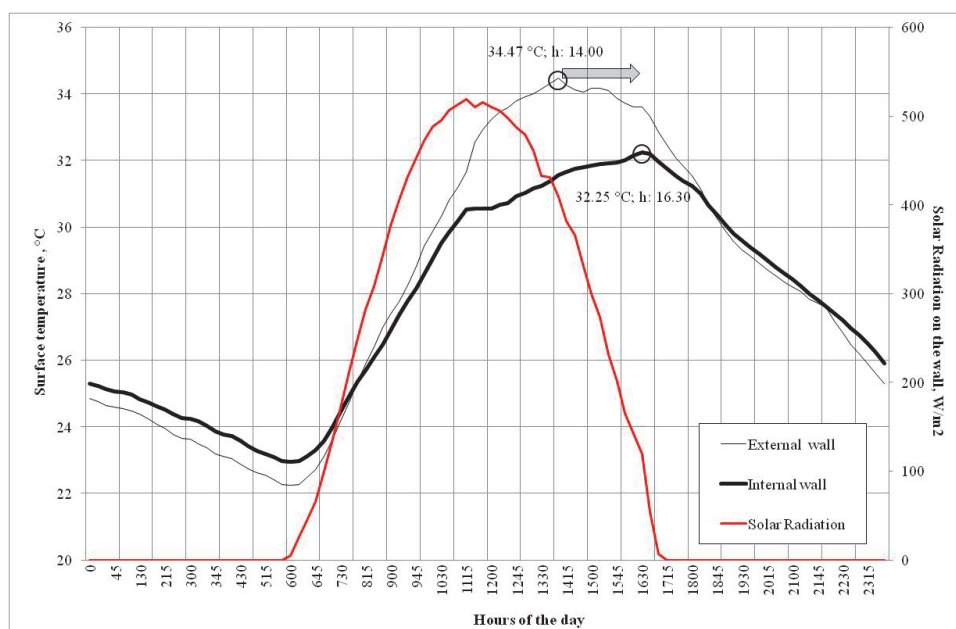


Figure 4 Solar radiation falling on the walls, surface temperatures of the inner side (internal wall) and of the external plaster exposed to solar radiation (external wall) for the wall covered with 66, 23 August 2014.

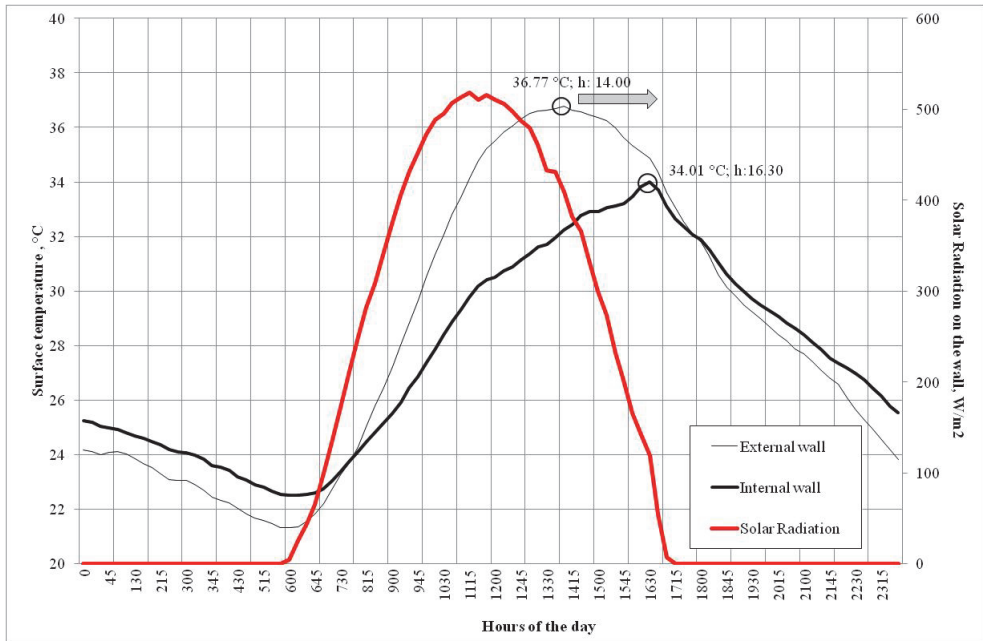


Figure 5 Solar radiation falling on the walls, surface temperatures of the inner side (internal wall) and of the external plaster exposed to solar radiation (external wall) for the uncovered control wall, 23 August 2014.

CONCLUSIONS

The application of the green vertical walls in order to reduce the heat gain due to solar radiation allowed a reduction of the external surface temperature up to 4 °C. The entire surface of the walls was not completely covered by vegetation and this reduced the positive shading effect of the plants layer. The experimental test was conducted on vegetated vertical systems during summer 2014 in South Italy and so the results concern only the warm period. Research will continue also in the autumn, winter and spring.

Green roofs and vertical gardens systems represent a class of plant technology with a high potential to be used as innovative solutions for improving energy efficiency and saving in the sector of construction industry. The greening technology can be used as a biological insulation system either for reducing energy for conditioning in summer or to increase the thermal properties of buildings in winter. In addition, these natural insulating systems can also improve the quality of air and the aesthetical impact of buildings in high constructed areas in cities, and have the potential to recreate natural ecosystem with trees, bushes and crops and thus contributing also to combat the global climatic changes by decreasing the urban heat island and the CO₂ emissions in the city's centers.

ACKNOWLEDGEMENTS

The present work has been carried out under the “Piano triennale 2012-2014 per la Ricerca di Sistema Elettrico Nazionale, progetto C.2 ‘Sviluppo di modelli per la realizzazione di interventi di efficienza energetica sul patrimonio immobiliare pubblico’, Piano Annuale di Realizzazione (PAR) 2013”, funded by the Italian Ministry of Economic Development.

The data processing and the editorial work must be shared, within the competencies of the research groups, equivalently among the Authors.

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ANALYSIS OF AN UNDERGROUND CELLAR THERMAL BEHAVIOR BASED ON ENERGY SIMULATIONS

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SUMMARY

The present study aims to assess the suitability of a non-conditioned underground room to keep and preserve the wine. In the last years simulation software helped the professional to predict temperature trends in aboveground buildings. Usually calculation precision and accuracy is not guaranteed for underground rooms. In order to assess suitability in underground rooms, this work calibrate an ad-hoc model and use it for the temperature prediction. Specifically the work, based on an Italian case-study, evaluates three models of the same underground cellar for predicting surface and air temperature trends. The differences among models came from different hypothesis of ground data availability. The results returned by EnergyPlus simulations are compared to case-study monitored data and undergo a procedure of validation and acceptability. The work shows the three model simulations are reliable and return acceptable results according to the proposed method, demonstrating moreover EnergyPlus program can be used also for heat exchange between ground and building. Finally the best fitting model have been used to predict room temperature trends throughout one solar year.

Key words: energy simulation, experimental calibration, underground cellar, winery design

INTRODUCTION

Preservation and ageing are important procedures having allowed populations to have food availability throughout the centuries, even during hard seasons or war periods. One of the technique to preserve food, including wine, is to keep the food within proper humidity and temperature conditions. A literature review, specific for wine, shows different ideal

values of temperatures and humidity typical for each kind of wine (Marescalchi 1965; Vogt 1971). Even though there is no uniformity in ideal temperature identification, they all approximatively agree wine temperature (as other food temperature) should be within 10°C and 20°C degrees. These temperature are close to the outside year average temperature for Mediterranean region and they are very similar to underground room environmental conditions. For this reason, several architects' treatises provided design criteria for food preservation and ageing rooms (Alberti 1565; di Giorgio Martini 1967). Specifically they suggested to keep goods (i.e. wine) in underground rooms since surrounding ground thermal properties can favor the maintenance of thermal and hygrometric conditions suitable for the food preservation and ageing. In the last decades, conditioned rooms have been preferred to underground rooms because of economic reasons – air conditioning systems are generally cheaper than underground excavations – and technical reasons – systems can guarantee high precision for room environmental condition control against an energy consumption related to the boundary conditions (outside temperature, construction materials, site, orientation etc.). Recently winemaking farms showed a renewed interest in underground buildings due to the energy cost rise, new energy-saving-oriented laws (European Commission 2010), existing building reutilization and customer sensitivity for tradition and sustainable production.

Nowadays, building design can take advantage of computer simulations in many construction fields, including thermal behavior prediction. These simulations can be important tools since help the professionals to optimize the design and make rooms suitable for the hosted function, in particular for non-conditioned rooms where no system can fix design errors or imprecision. Several energy programs can provide precise temperature trend prediction for buildings. Even though simulations are allowed and calculated for underground rooms too, many programs do not guarantee their returned results precisions because of the different heat transfer that occurs in underground rooms. These programs, in fact, accurately simulate the aboveground construction thermal behavior calculating the heat transfer, between the building and the outdoor environment, as one-dimensional phenomenon and considering one-hour time steps. On the contrary energy transfer between the ground and the construction should be modeled as two (or even three) dimensional phenomenon and it is a process that involves longer time scale (monthly scale). A recent research made by Mazarrón, Cid-Falceto, & Cañas Guerrero (2012), studied the problem in depth, showing precise results can be achieved also for underground construction using proper modeling and no software implementation. This paper is based on Italian case study and shows how to simulate the thermal behavior in an underground room and assess its suitability to host wine. This aim is achieved through two phases: calibration and simulation.

METHODS

Case study

This work is a part of a wider research that aims at defining specific building design criteria, oriented to the landscape integration (Tassinari et al. 2013), functional design (Torreggiani et al. 2011), natural indoor ventilation (De Rosis et al. 2014) and energy efficiency (Benni et al. 2013), for small-medium wine growing and producing farms, based on experimental data elaborations (Barbaresi et al. 2014; Tinti et al. 2014). For this research

a wine ageing room sited in “Azienda Agricola Branchini” farm, settled in Bologna (Italy), has been chosen as case study (see Figure 1). The room (hereinafter called “Cellar”) is an underground part of two-story building, is a parallelepiped north-east oriented 9.80 m long, 5.60 m wide and 2.60 m height. The volume is totally underground, a door is located on the north-west wall and a basement window on the north-east wall. The walls are made with 25 cm thick masonry, floor with baked clay bricks on a 20 cm of concrete slab, ceiling by a 30 cm of hollow concrete slab. The cellar is naturally ventilated whilst the above room is a conditioned residential space. Since the whole research is based on experimental calibration, a survey equipment was tested and set in the farm buildings. The survey allowed to collect data about Cellar indoor air temperature and weather data. The survey started in June 2012, the recording frequency was set in 30 minutes and is still in progress. The installed sensors are standalone data-logger PCE-HT71. For the purpose of this work they are used uniquely as thermometers, resolution is 0.1°C , accuracy $\pm 0.5^{\circ}\text{C}$. A literature review shows that many researcher identified ideal temperatures for wine ageing, these values are strictly dependent on kind and quality of the wines, therefore there is no homogeneity in ideal temperature definitions. The interval taken as reference for temperature homogeneity hypothesis and suitability assessment is $\pm 1.0^{\circ}\text{C}$, since the centigrade unit is the smallest unit of temperature considered. Accuracy and resolution have been chosen according to the precision required by the study. Finally the test showed the cellar can be considered as a single thermal zone (homogeneous temperature) and identified the best position for the data-loggers installation. During the test the temperatures of the north east wall (hereinafter called Wall) were monitored as well. Recorded data demonstrated that the wall temperatures are similar to cellar temperatures but vary slower. Considering many barrels located close to the wall can be affected by the wall temperature, a further sensor was placed sticking to record the wall temperatures. The equipment layout is showed in the Figure 2.



Figure 1 The Cellar

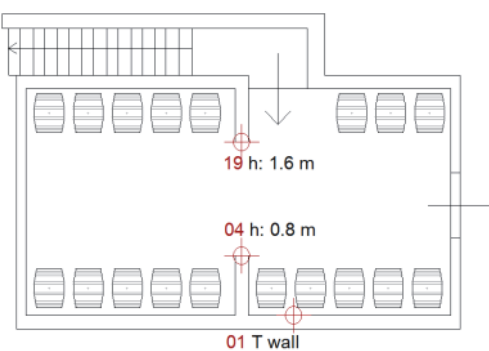


Figure 2 Survey equipment layout

In order to achieve a precise model calibration, outdoor weather data are necessary. Many database provide weather data recorded in stations close to the case study (i.e. Bologna Airport, 32 km north west far) but they often represent a typical meteorological year. For the calibration, weather data shall be recorded simultaneously with the wine

ageing room data, for this purpose main weather data (such as temperature, humidity, pressure, wind direction, wind speed and others) were collected by a weather station 100 m far from the Cellar. To complete case study survey, physics characteristics of the ground have been taken from geological reports edited for the building construction and from literature (Martelli and Tinti 2012)

EnergyPlus software

The energy software used for this study is Energy Plus 8.1 released by the U.S. Department of Energy (DoE). EnergyPlus is a whole building energy simulation program used to calculate energy loads and temperature trend prediction in buildings. Periodic tests made by the DoE prove the EnergyPlus calculation reliability for aboveground heat transfer calculations, diversely the user manual warns about underground simulations explaining EnergyPlus one-dimensional conduction calculation “causes severe modeling problems irrespective of the methods being used”. The modeling phase was made with Open Studio 1.4. One of the most important phase in modeling, is the thermal zone subdivision, the software in fact needs the building divided in portions of space composed by an air volume at uniform temperature and by its boundary surfaces (thermal zones). The temperature test made in 2012 showed the Cellar can be considered as single thermal zone (see Sec. 0).

The input phase allows to insert the monthly average ground temperatures (Ground Temperature : Building Surface object) and they are associated to the external side of the underground walls. Temperature values are not calculated but inserted by the user. Few models for ground temperature prediction in function of depth and time of the year exist, but their validity is proven for undisturbed ground and for depth higher than 5-10 meters. One of the most used is Kusuda and Achenbach (1965) model:

$$T_g(d, t) = T_m - A_s \cdot \exp \left[-d \sqrt{\frac{\pi}{365 \cdot \alpha}} \right] \cdot \cos \left[\frac{2\pi}{365} \cdot \left(t - t_0 - \frac{d}{2} \cdot \sqrt{\frac{365}{\pi \alpha}} \right) \right] \quad (1)$$

$T_{(d,t)}$ is the mean ground temperature [°C] at depth d [m] on day t of the year, T_m yearly mean surface ground temperature [°C], A_s yearly temperature amplitude at the surface [°C], α ground thermal diffusivity [m²day⁻¹], t_0 day of minimum surface temperature. Mazarrón, Cid-Falceto, and Cañas Guerrero (2012) elaborated an ad-hoc modeling for entirely underground rooms, the validation was made comparing two case-study cellar indoor air temperatures with EnergyPlus returned values, throughout three years.

Run period definition

The aforesaid temperature survey has allowed to record indoor temperatures since the June 2012. After one year (June 12th 2012 - June 11th, 2013) the collected data were used for the model calibration. After a comparison between recorded data and log activities occurred in the cellar, two periods have been excluded since indoor activities, non-compatible with standard room operations, modified the typical room temperature trend. These periods are: June 13th 2012 - August 25th, 2012 (fans were used to eliminate odor coming from recent restoration) and October 29th, 2012 - November 11th, 2012 (a prolonged window opening dropped down the temperature). The recorded temperatures of the Cellar and of the Wall during the run period are shown in theFigure 3. Finally the temperatures useful for this work are 6692 representing the 76% of the total 8760 hours per year. The

recorded temperatures have been collected in two arrays T_{rc} and T_{rw} respectively the Cellar temperatures and the Wall temperatures.

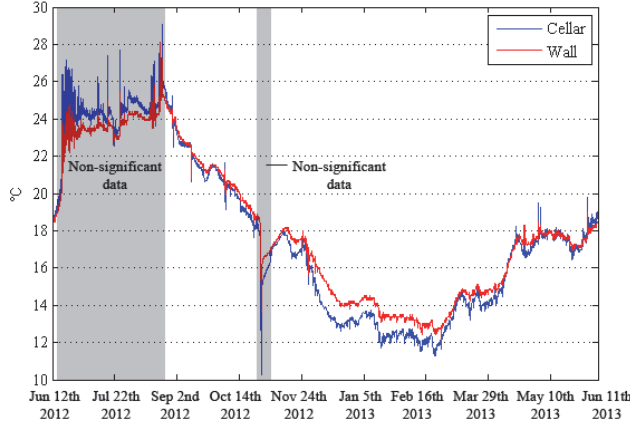


Figure 3 Recorded temperature trends

Case study modeling and simulation

In order to calibrate the model and to find the best model solution three different alternative models have been tested comparing the results and the recorded temperatures. They are based on a common cellar Energy Plus model concerning the aboveground construction, the openings, the air filtration rate and more. The three models come from different hypothesis of ground data availability and differ for the ground and wall modeling.

The cellar was modeled according to the following hypothesis: minimum, maximum an average underground indoor wall temperatures and the day of minimum temperature are supposed available. Starting from the abovementioned values, the Wall temperature trend is created as a sinusoidal function similarly to ground temperature trends. The function is calculated from the Kusuda formula (1) inserting some corrective values in order to get a temperature curve (see Figure) having same mean, amplitude and day of minimum temperature as the cellar interior Wall:

$$T_g(d, t) = T_m + T_c - (A_s - A_c) \cdot \exp \left[-d \sqrt{\frac{\pi}{365 \cdot \alpha}} \right] \cdot \cos \left[\frac{2\pi}{365} \cdot \left(t - (t_0 + t_c) - \frac{d}{2} \cdot \sqrt{\frac{365}{\pi \cdot \alpha}} \right) \right] \quad (2)$$

where $T_c = +4.83^\circ\text{C}$, $A_c = -2.02^\circ\text{C}$ and $t_c = +56$ days, are the corrective values generated. Finally the Ground Temperature: Building Surface object is generated as the monthly average of the values calculated with the Formula (2). These values are applied to the exterior face of the buried walls that are modeled as 25 cm thick masonry.

The model considers interior wall temperatures available since deduced by a thermal survey. Therefore the Ground Temperature: Building Surface object is created calculating the monthly temperature averages using the survey data. The walls are modelled with null heat capacity and thermal resistance (see Figure 5a).

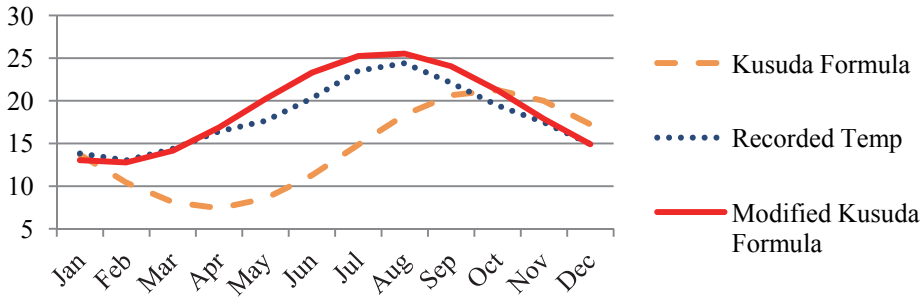


Figure 4 Underground temperature for Model A

In this configuration available data concern the ground thermal characteristics, in particular ground type, density and thermal conductivity are supposed available. In order to simulate the ground thermal behavior, the ground surrounding the cellar is created as thermal zones according to Mazarrón, Cid-Falceto, and Cañas Guerrero (2012). Material of the boundary walls between the Cellar and the ground are composed by two materials: 25 cm thick masonry and a fictitious material with null heat capacity and thermal resistance [$\text{m}^2\text{K/W}$] equal to a ground layer as thick as the ground fictitious thermal zone (Figure 5b).

Simulations

EnergyPlus simulate one solar year and, among several output variables, returns hourly indoor air temperatures (Cellar) and interior surface temperatures (Wall). These values are compared with the mean of data-loggers 04 and 19 (Cellar) and with data-logger 01 (Wall). The output variable time interval is set in 1 hour. Considering EnergyPlus run period is the solar year, two simulations were run, the first for the solar year 2012 and the second for the 2013, in order to make simulated and recorded data comparable.

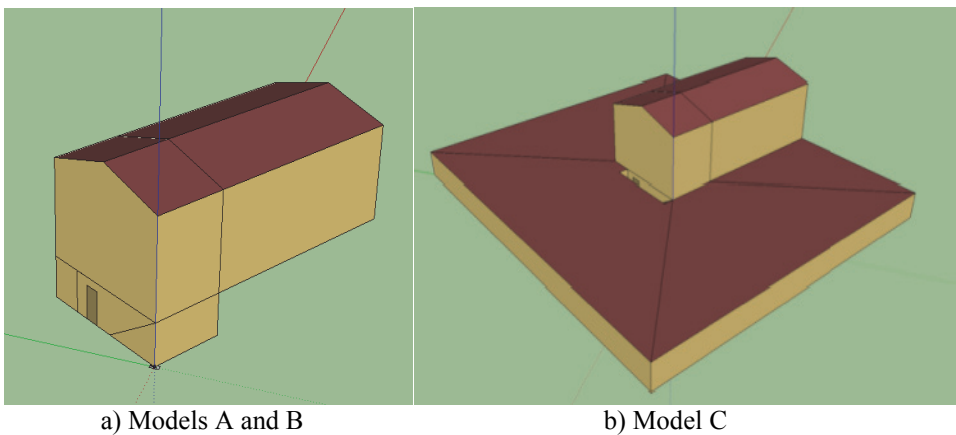


Figure 5 Open Studio model phase

The 6692 temperatures returned by the simulation, corresponding to the survey period, are gathered in two arrays, one for Cellar temperatures T_{sc} and one for Wall temperatures T_{sw} . All other results provided by the simulation are not considered. The computer used for EnergyPlus simulation has the following characteristics: Intel(r) Xeon(r) processor, CPU 3.06 GHz, RAM6.00 GB, operative system Microsoft Windows 7 64bit.

Reliability and precision analysis

The validation of the model is divided into two phases: the first takes into consideration the thermal behavior, the second the acceptability of temperature differences between model and survey.

As described in the Section 0 the centigrade unit is considered as the reference value. Using this value, two reference array are generated T_{r-1} and T_{r+1} where the i -th element is defined as follows: $T_{r-1,i} = T_{r,i} - 1^\circ\text{C}$ and $T_{r+1,i} = T_{r,i} + 1^\circ\text{C}$, where $T_{r,i}$ is the temperature recorded at the time step " i " in the Cellar. The arrays T_{r-1} and T_{r+1} can be considered as the temperature trend generated by two models that differ by 1°C in positive T_{r+1} and in negative T_{r-1} from the case-study recorded temperatures. These arrays are used as reference for the three models.

Before analyzing the result acceptability a correlation analysis has been done in order to verify the thermal behavior correspondence between models and reality. In this work thermal behavior is defined by the starting temperature and its variation for each time step. Cellar and Wall hourly temperatures returned by the simulation are compared with the respective monitored values for the three models investigated: T_{sc} compared with T_{rc} and T_{sw} compared with T_{rw} . Once compared, Pearson coefficient (r) and linear regression line ($y = ax + b$) are calculated. The more the values r , a , b are respectively close to 1, 1, and 0, the more the model and the reality have similar temperature and similar variation for every time step meaning they have similar thermal behavior.

The result acceptability is assessed comparing the errors made by the models (differences between simulated and recorded temperature) with the reference arrays. For each model the errors are collected in e_c (Cellar) and e_w (Wall), mean value and RMSE are calculated on e_c and e_w . Later e_c and e_w are compared with T_{r-1} and T_{r+1} . The i -th element e_i is defined as $e_i = T_{si} - T_{ri}$, where T_{si} is the simulated temperature and T_{ri} the actual temperature recorded at the time step " i ". Finally the errors are summed ($\sum e_{ci}$ e $\sum e_{wi}$) obtaining the error by excess (summation of sole positive errors), error by defect (summation of sole negative errors), total error (algebraic summation of errors), absolute error (summation of error absolute values).

These errors are expressed in degree-hours and represent the "thermal distance" between model and case study. The same procedure, applied to the T_{r-1} and T_{r+1} arrays, identifies a reference interval as shown in the Table 1. For the purposes of this study, model results are defined acceptable if the mean, the RMSE and the absolute error calculated on the arrays e_c and e_w are within the reference intervals as reported in the Table 1.

Table 1 Reference intervals

	°C		Degree-hours			
	mean	RMSE	Excess	Defect	Total	Absolute
Reference	+/-1.0	+/-1.0	0÷6692	-6692÷0	+/-6692	0÷6692

Cellar suitability for wine-ageing

Once the model that best fits the reality is identified, the simulation is repeated using the the solar year 2013 weather file. From this simulation is possible to obtain a reliable prediction of temperature allowing the professionals (i.e. oenologist) to have one of most important information to assess the cellar suitability for wine-ageing.

RESULTS AND DISCUSSION

The graphs in Figure 5 show comparisons between simulated and recorded data of the three models A, B and C. In particular it is possible to see the temperature trends – simulated (red) vs recorded (blue) – separated by models (A, B and C) and spot (Cellar and Wall). The Table 2 reports comparison summary. Once the best model is identified, the simulation results, obtained with a complete solar year, are shown.

Model reliability

As explained in the Section 0 the model reliability is assessed analyzing the regression line. In all models coefficient a , b and r are very close respectively to 1, 0 and 1. In particular the Wall in Model C is the closest (1.006, -0.195, 0.996) to the case study. This analysis shows Models and case-study have similar initial temperature and similar variation, in other word Models and case-study have the same thermal behavior.

Result Acceptability

The second analysis is about the result acceptability and is based on mean, RMSE and absolute error summation. As for thermal behavior, Model C shows the best results. In detail, Model A spots (Cellar and Wall) present similar results: mean error -0.400°C, RMSE 0.700°C, total errors 2600 dh (degree-hours), absolute errors 4300 dh. Comparing the error summation with the reference model, the Wall total error – that corresponds to mean error by definition – is 36% and Cellar total error is 41%, the Wall absolute error 64% and Cellar absolute error 65%. Observing the Figure 6 for Model B, the main input feature of the Model B is evident: the Wall temperatures are inserted as monthly average values. Logically, this modeling created the smallest mean error (0.042) against a high RMSE (0.840). Similarly the RMSE calculate on the Cellar of Model B is the highest of all modeling (0.911) and in this case the mean error presents elevate value (-0.650) compared to other simulation results. The error summations shows the Model B underestimate the temperature trends, in particular absolute error is very close to the reference value (6024 dh).

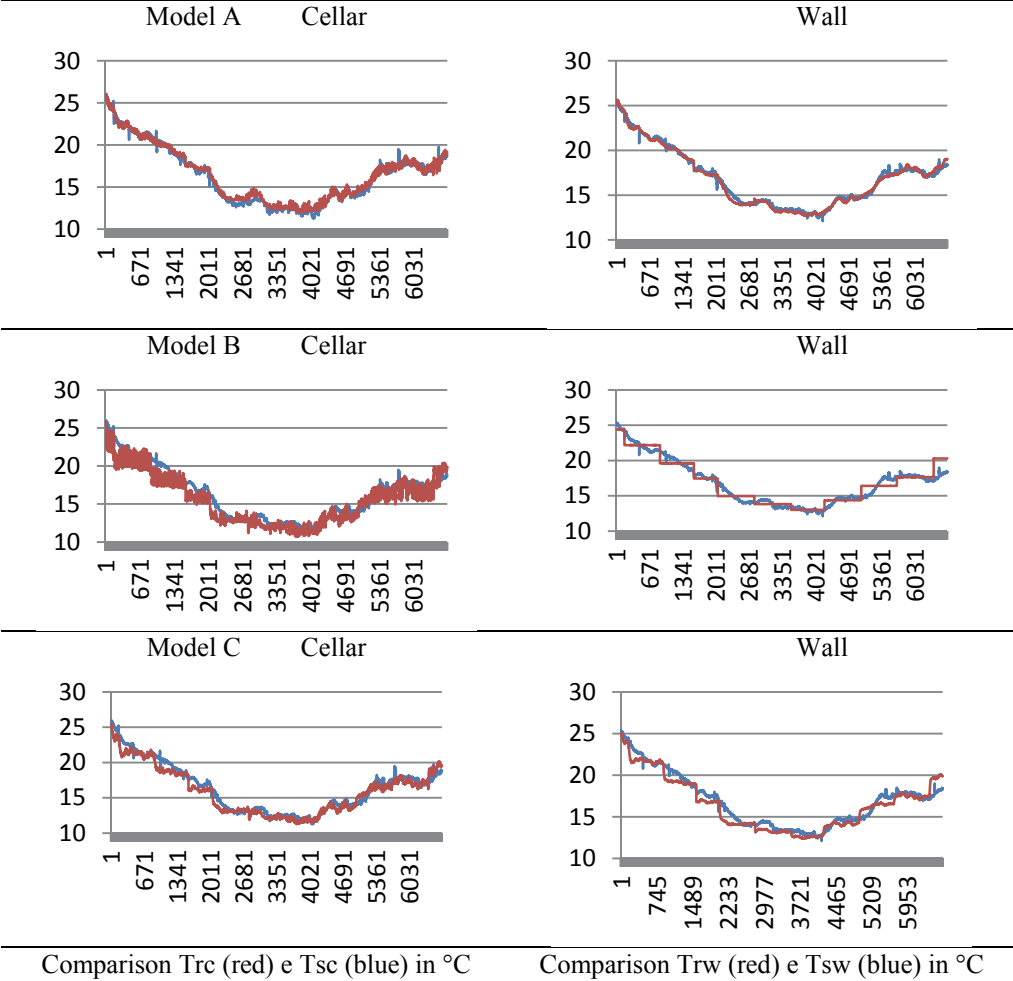


Figure 6 Temperature trends

Models global considerations

The most important result is the three models have thermal behavior similar to the case-study and the results are within the reference value, therefore modellings can be considered reliable and result acceptable for all the models. Specifically Model C appears to be more precise than Models A and B (except for the mean error calculated on Model B Wall). One of the possible cause of the lower precision for the Models A and B, can be found in the EnergyPlus ground temperature input procedure. EnergyPlus allows the input ground temperature just as twelve monthly average temperatures. In the three models, Wall results are more similar to the case-study than Cellar results.

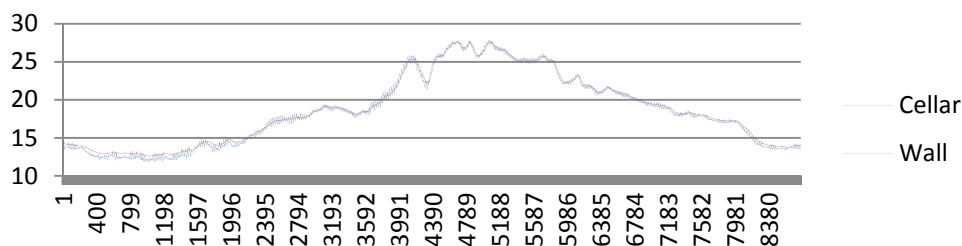
Table 2 Summary table

	Time (s)	Model reliability			Model Acceptability				
		(r)	(a)	(b)	mean (°C)	RMSE (°C)	Excess	Defect	Total
Reference					+/-1.0	+/-1.0	0÷6692	- 6692÷0	+/- 6692
Model A	57.19								
Cellar		0.994	0.952	0.975	0.194	0.395	1832	-531	1301
Wall		0.996	1.006	-0.195	-0.086	0.296	537	-1115	-577
Model B	22.00								
Cellar		0.964	0.948	0.203	-0.650	0.911	837	-5188	-4351
Wall		0.963	0.947	0.929	0.042	0.840	2241	-1962	278
Model C	25.37								
Cellar		0.980	0.936	0.639	-0.411	0.689	762	-3516	-2753
Wall		0.972	0.964	0.240	-0.363	0.734	958	-3389	-2431

This result is logical considering that the wall simulation is not affected by factors hard to manage in simulation such as air ventilation and infiltration. Finally, the time taken for simulations is longer – more than double – for the Model C compared to the other two Models. This difference is due to the complexity of model C. The fictitious zones and materials, in fact, increase the number of variable (such as surfaces and volumes) involved in calculation.

Cellar suitability for the wine ageing

Once defined that C is the model that best represent the case study, simulation is repeated using the 2013 weather data as EnergyPlus weather file. The return data (showed graphically in the Figure 7) give important information about temperatures that can help to assess the Cellar suitability to host wine. These data are simply reported in this study since their suitability can depend by many factors (such us: vine type, wine quality and others) not treated in this work.

**Figure 7** Temperature trends for room suitability assessment

CONCLUSIONS

All the three models analyzed in this work, returned acceptable results according to the proposed method, demonstrating EnergyPlus software can properly calculate also heat exchange between ground and building. Notice that result acceptability is function of the precision required in the research goal. The three models – corresponding to different hypotheses of data availability – can be used according to the data availability. The Model C (ground modeled as thermal zone) appeared the more precise and, considering the ease and the cheapness in finding input information, can be the recommended model unless the calculation time is a crucial issue. This is a typical situation during preliminary design since often speed is preferred to precision. Another important result is the extension of the validity of Mazarron models to the wall temperature trends since wall temperature is an influential factor both in EnergyPlus simulation and in wine-ageing. Results show Model B and C accuracy is strictly dependent on the ground temperature input phase, the Ground Temperature : Building Surface object, in fact, allows the insertion of twelve ground temperatures, one per month. Increasing the number of temperature in input (for example 2 temperatures per month) can improve the result precision. The work finally show that these analyses can lead to a proper underground room energy simulations that return accurate temperature trend prevision in non-conditioned wine-ageing room, allowing the professional involved in the wine processes to assess the room suitability to keep, preserve and age the wine. Similar studies can be carried out to humidity and indoor ventilation as well, in order to get a complete assessment of the room suitability.

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SWOT ANALYSIS AND LAND MANAGEMENT OF PLASTIC WASTES IN AGRICULTURE

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ABSTRACT

Plastic materials are generally used for several agricultural applications and, at the end of their lifetime, they produce high volumes of waste to be disposed. A non suitable disposal system for agricultural plastic waste could induce economical damages, negative effects on the natural landscape and on the agro-ecosystem with loss of material or energy. Optimizing the processes of collection, transport and final disposal, the agricultural plastic wastes become "secondary raw materials", technically efficient and economically feasible, that can be re-used for also other different applications. The problem of the management of the plastic waste flux coming from agricultural activities is still far to be solved in some Italian areas. In the present paper the management of agricultural plastic wastes was evaluated by means of the SWOT (Strengths Weaknesses Opportunities Threats) analysis and the application of a Geographical Information System (G.I.S). The methodology was applied to the municipality of Trani, in the Barletta, Andria, Trani Province (BAT), in Apulia Region, South Italy. The SWOT analysis was used to evaluate the whole process concerning the waste management, the GIS methodology was used to quantify plastic wastes generation on the land.

Key words: covering film, vineyard, G.I.S. methodology, agricultural waste valorization

INTRODUCTION

The strategic contribution of plastic materials to the development of the agricultural sector is testified by their increasing use, stimulated by a constant research of new polymers

and blends by the chemical industry, for crop protection, soil mulching, irrigation and drainage, packaging during harvesting, transport, storage and sale of agricultural products (Picuno et al., 2012; Espi et al., 2006; Vox et al., 2010). Innovative plastic films and nets have enabled a significant increase of the productivity in protected cultivation in Italy as well as in every Country in which the agriculture is most intensive with high value added. Apart from their diverse use and contribution to a significant increase in productivity, the use of plastics causes high quantities of post-consumer material that need to be disposed of in such way that it will not cause negative effects on the landscape and the agro-ecosystem (Al-Maaded et al., 2012; Briassoulis et al., 2012; Briassoulis et al., 2013; Briassoulis et al., 2014; Delbert and Hemphill, 1993).

The management of the plastic wastes is very expensive by the public authorities since the farmers commonly use unacceptable disposal practices, ignoring the negative effects produced. The complexity and continuing evolution of the Italian legislation and the non uniform legislation across EU make the situation more complicated. Thus, in Italy only the 30 % of post-consumer agricultural polyethylene (PE) is collected and recycled by the National Consortium “PolieCo” (PolieCo, 2014).

The management of the agricultural plastic wastes (APW) could be taken more seriously because they could produce new secondary raw material (Sica et al., 2012; Picuno et al., 2011; Picuno, 2014) or even energy, considering that many polymers are recyclable and that the plastic is characterized by an high heating value, since deriving from the fossil-oil (Delbert and Hemphill, 1993; Scarascia Mugnozza et al., 2012).

The management problem of the plastic waste flux, coming from agricultural activities, is still far to be solved in some Italian areas as in the territory of the Barletta, Andria, Trani Province (BAT), in Apulia Region, South Italy, which is an agricultural area typically suited for vineyards. Nevertheless the local Authority of the BAT Province is interested to introduce modernization actions for the farms in the area. This was discussed, together with other Italian and Greek Partners, in the project “AWARD” (AWARD, 2014) in order to solve the diffused problem of the APW mismanagement.

The aim of the present research was to carry out a study in order to evaluate the problem of the agricultural plastic waste generation and management in the municipal area of Trani in the BAT province. Preliminary a SWOT (Strengths Weaknesses Opportunities Threats) analysis was carried out in order to define the framework of the APW management in the municipal area of Trani; strengths, weaknesses, opportunities and threats were pointed out. Based on this analysis a Geographical Information System (GIS) was used in order to define the waste generation points and the more vulnerable areas in the land. GIS was chosen as suitable tool able to provide updated and detailed information to the decision makers.

MATERIALS AND METHODS

The focus area of the research was the municipal territory of Trani, included into the Province of Barletta-Andria-Trani (BAT), an Italian province in the north of the Apulia Region (Fig. 1).

The SWOT analysis, commonly used in business management as useful tool in strategic decision-making, can be used to improve waste management systems in urban areas

(Srivastava et al., 2005), in industrial areas (Zamorano et al., 2011; Mbuligwe and Kaseva, 2006), and in protected areas (Scolozzi et al., 2014). In this research, the SWOT analysis was carried out to analyse the strengths, weaknesses, opportunities, and threats regarding the APW management in the municipal territory of Trani. By means of the SWOT analysis it is possible to recognize the internal strengths and weakness of the collection and management of APW in the research area, as well as the external opportunities and threats that the local community potentially faces. Strengths, as internal elements and factors, contribute to the achievement of the objectives; weaknesses, as internal structural characteristics, hinder the attainment of the objectives; opportunities, as external situations, must be used to minimize both internal weakness and external threats; threats, as external unfavourable situations, trends or impending changes, might negatively affect the achievement of the goals (Srivastava et al., 2005; Zamorano et al., 2011; Houben et al., 1999; Zhang, 2012). SWOT analysis can be applied to identify action plans for the implementation of waste management from the viewpoints of economic, ecological and social sustainability (Srivastava et al., 2005; Zamorano et al., 2011).

A Geographical Information Systems (G.I.S.) is a suitable tool for the management of the APW flux (Scarascia Mugnozza et al., 2008) thanks to its attitude in synthesizing complex land relations (Toccolini, 1998). GIS is an effective computer tool able to collect, store, retrieve, transform and display spatial data; it is possible to integrate and handle huge amounts of data quickly (Rogge et al., 2008; Lee et al., 1999; Tortora et al., 2015). Data are organized in layers which can be combined and integrated in order to produce useful information about a region or a phenomena (Rogge et al., 2008; Lee et al., 1999).

In this paper the GIS-based planning instrument was used to evaluate agricultural plastic waste generation over the land. Among all the used plastics, as a example, plastic wastes generated in protected cultivation were evaluated. The attention has been focused on the areas with vineyards because, among all the crops in the area of Trani, vineyards are particularly identified as major contributors to the generation of plastic waste. Covered vineyards use plastics for the covering system as well as for pipes and containers: one square meter of vineyard covered with plastic films can produce up to 0.2 kg of plastic waste, only for the covering film.

An adequate base map was chosen for finding the main agro-environmental and infrastructural components characterizing the territory. The base map material used was:

- Regional technical map (CTR) at a scale of 1:5,000 and placed in the WGS 84 / UTM zone 33N reference system, obtained from an aerial flight performed in 2006;
- Digital color orthophoto at a scale of 1:5.000 with a pixel ground resolution of 50 cm obtained from an aerial flight performed in 2011, placed in the WGS 84 / UTM zone 33N reference system;
- Land use map of the Region of Apulia at a scale of 1:5,000 with legend complying with the European CORINE Land Cover Changes Database and an extension to the fourth level. This map derives from an orthophoto having 50 cm pixel, land use polygons are based on the same geometric elements of the Regional technical map.

The information about the municipality boundaries and infrastructural components were derived from the CTR. The ESRI ArcMap10 was used as GIS software.

RESULTS AND DISCUSSION

The results of the application of the SWOT analysis are shown in Table 1. The Strengths are the favourable natural environment, the presence of agricultural productive chains, good road infrastructures, an active tourist area, the attitude of the population to collect differentiated Solid Urban Waste and the possibility to collect homogeneous APW in the municipal territory of Trani. The weaknesses are connected to the development of the intensive agriculture and to the low diffusion of the biological agriculture, to the lack of suitable facilities and of guidelines for APW management, and to the low level of knowledge of the farmers. At the same time, Opportunities can be the increase of job positions due to a good management of APW, the increase of Tourism demand with an extension of the tourist season, the reduction of some transport, collection and cleaning costs, the reduction of the use of non-renewable sources, the reduction of environmental pollution. Threats have been identified with the lawmaking of new and complex rules, the increase of the agricultural practices that use plastic materials, and the low level of communication between local Authorities and farmers or Association of farmers.

Summarizing, the SWOT analysis contributed to achieve the followed aims:

- definition of optimized process of APW collection and treatment;
- generation of the conditions for a better awareness about the APW situation;
- spontaneous creation of new entrepreneurship in the field of APW management and recycling.

The whole territory of the Province BAT could benefit of this SWOT analysis since the results could affect the landscape and the social-economic conditions of the inhabitants, with particular regard to farmers, collectors, transporters and recyclers.

Table 1 SWOT Analysis results for the municipal territory of Trani

STRENGTHS	WEAKNESSES
Favorable natural environment. The territory is flat, crossed by numerous superficial erosive grooves, called “blades”; the coast is rocky, with high and continuous cliffs. The north area is characterized by many brackish water sources, important natural habitat for many and different animal and plant species. The Mediterranean climate (hot and dry summers) promote bathing tourism. Presence of agricultural productive chains, significant both for the quantity and the quality. The municipal territory, as the whole Apulia Region, is enumerated among the best and strong agricultural Italian areas, benefiting by natural and favorable resources, as the soil-climatic characteristics; they allow a good development of the typical Mediterranean cultivation: mainly	Development of the intensive agriculture. One of the environmental problems characterizing the territory of Trani is connected to the agricultural sector because the productive processes use high amounts of plastics (from the nets to the covering films, from the irrigation pipes to the agrochemical containers, etc.). These quantities are often mismanaged and their disposal is not suitable both for the health of the all living beings and for the whole ecosystem, causing environmental impacts, irreversible contamination of the air, soil and groundwater, and economic damage. Lack of suitable facilities. The lack of suitable facilities contributes to making the environmental situation worse. The number of the ecological platforms for first collection or storage is very small. Most of them are not enough suitable and

table grapes of high quality, widely marketed. Road infrastructures. Trani is crossed with the national road that allows fast connections both to north (Barletta and Foggia) and south (Bari). It is near to the motorway A14 Bologna-Taranto that insures the long-distance connections on the north-south axis. Provincial roads connect Trani to the nearer municipalities. The transport of APW could easily be performed from farms to the ecological platforms and/or final disposal centres.

Tourism. Trani is considered "town of the art" due to its wonderful artistic and architectural treasures (the famous cathedral on the sea and the Castel of the Svevi's dynasty, churches, monasteries, valuable historical buildings and the ancient tourist port) that recall its glorious age-old history. The local Authorities are very diligent to offer events, shows and demonstrations, many of which on the evaluation of the typical products. The preserving of the rural landscape and the environment improves the quality of the offered goods and meets the demand of the tourist.

Differentiated collection of Solid Urban Waste. The collection of the solid urban waste is widespread and practiced by citizens; consequently, schemes of differentiated collection for the APW, according their typologies (net, film, container, etc.), could be considered and easily practicable both by the local Authorities and people/farmers. Economic incentives could also be provided on APW.

Homogeneous streams of APW. The territory is suited for viticulture; so the flows of the APW are enough homogeneous and a good selected collection is already upstream with reduction of the selection costs. Transport costs may also be limited since the transporters should go to the right ecological platform and/or centres of final disposal on the basis of the waste typology.

they do not have specialized personnel; therefore, the APW cannot be subjected to the preliminary works (verification of the delivered waste, differentiation of the waste typology, differentiation of the polymers, washing, compacting, shredding, etc.) in order to obtain optimal products for the final disposal.

Low level of knowledge of the farmers. Farmers have a low level of knowledge; they show little attention to the updating and training in the agriculture due to their high average age.

Lack of guidelines for APW management. Farmers have not any guidelines for APW management; besides, they don't often know very well: 1) the regulatory aspects (Community and National rules) which are always evolving and are difficult to understand; 2) the damage occurring to the living beings and to the whole ecosystem if they don't act according to the Italian Law in force; 3) the authorized National Consortia for the collection of waste agricultural plastics (PolieCo); 4) the heating value of plastics. Farmers, unaware, deliver the post-consumer plastic films to unauthorized personnel, increasing the illegal waste trade towards Asian countries.

Low diffusion of the biological agriculture. There is a low diffusion of the biological agriculture in this area. In order to protect the crops by every typology of pathogens and to sell them in very well conditions, farmers unfortunately use large quantities of agro-chemicals (insecticides, herbicides, fungicides, etc.) that are contained and commercialized in bottles, cans, bags realized with plastic materials in the 90% of cases.

OPPORTUNITIES

Jobs. A good management scheme of the APW may origin positive social results due to the increase of job positions for every municipality in Trani. There may be new jobs such as authorized transporters that collect the APW from the farms and bring them to the ecological platforms. Other job positions could be related to the staff working at the ecological platforms,

THREATS

Lawmaking of new and complex rules. Considering both, the continuous evolution of the rules on agricultural waste isn't always clear and straightforward.

Increasing of the agricultural practices that use plastic materials. The potential increasing of the waste streams can be due to the change of the land use, such as the greater diffusion of some

such as the operators for the reception and weighing of the APW, specialized operators that may inspect and validate the quantity and the quality of the waste received (e.g. cleaning and differentiation). All that to improve the value of the waste. In fact, a "good quality" waste can origin a good new secondary material to send to the correct final disposal. Some specialized operators may attend training courses and update their knowledge on APW in order to transfer it to the farmers.

Increasing of the Tourism demand. An optimal management scheme is indispensable because an un-compromised or congested landscape by the APW is more easily exploitable. The eligible territory is rich both in rural heritage and in many other constructions (castles, towers, churches, etc.) of high architectural and historical value therefore cultural and environmental paths can be realized both in coastal and inland areas. In this way, the territory becomes an attractive place for the tourist "friend of the environment" to which can offer quality products, typical for the area. These products may be consumed on the premises (farms) or bought, perhaps together to the handmade product, causing social and economic positive consequences. This can be a suitable alternative to the bathing and contemporary a way to extend the tourist season.

Reduction of some costs (transport, cleaning), of non-renewable sources use and of the environmental pollution. The creation of an optimal management and disposal system of the APW combines environmental protection and economic needs. The enhancement of the wastes (by the material and energy recovery) causes reduction both of some productive costs and of the use of non-renewable sources. At the same way, the increase of the quantity of the recycled products would cause a costs reduction of the productive processes at the same time improving their quality that will lead to their increasing demand on the market.

crops that require use of plastic materials (e.g. Table grapes); the situation may further worsen for the failure adjustment by the farmers.

Low level of communication between local Authorities and farmers or Association of farmers. The lack of synergy between local Authorities (e.g. regional and municipal Departments of the Agriculture) and Associations, due to political and economic interests, could only protract the time to solve the problem and increase the environmental threats and the damages to the rural landscape and the health of each living being.

The SWOT analysis showed that the area of Trani is suitable for the application of an efficient waste management system. In the Trani municipality the land surface is equal to 10238 hectares of which the 85 % is the agricultural surface. The most common agricultural practice in the region are the cultivation of olive trees (66%) and vineyards (14%). Generation point of plastic waste (plastic films, nets, containers and pipes) must be

preliminary localized all over the land; critical point of generation of APW are individuated where crop protection is realized.

The data on the spatial distribution of the vineyards were obtained from the thematic Land use map (Fig.1). Land use map gives information only about the presence of vineyard, but no information about the coverage of the cultivation structure and on the kind of covering material, i.e. plastic film or net is available. The implemented methodology of territorial analysis, realized by means of a GIS, permits to geo-reference the crops according to their typology and to make a further classification according to the presence or not of a covering system, and to the covering material used (plastic film or net). This methodology allows the data acquisition, otherwise hardly obtainable, on the use of plastic materials in agriculture. Actually, the information obtained cannot be directly extracted through the analysis of a land use map. Besides, it is not possible to easily collect them through questionnaire based systems because of the low level of farmers knowledge and the low level of communication between local Authorities and farmers or Association of farmers, as pointed out by the SWOT Analysis.

A restricted area within the Trani municipality, characterized by a high density of vineyards, was evaluated as case of study only for vineyards plastic waste generation (Fig. 2).

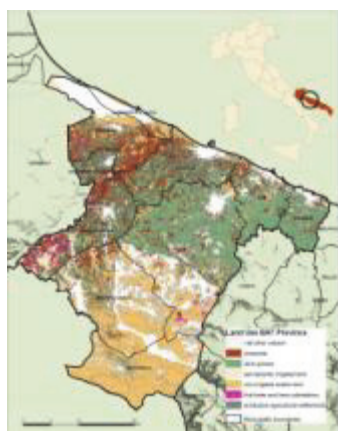


Figure 1 Land use map of the BAT Province, Apulia Region



Figure 2 The area with high density of vineyards cultivations.

A dedicated georeferenced database was created using the maps in a GIS environment with the support of ESRI ArcMap10 software. The created database was, then, enriched with more detailed data on spatial distribution and typology of vineyard, and on the plastic films or nets employed for their cultivation; these data were obtained by the overlay mapping of the above cited maps and by the parallel operation of photo-interpretation of the web-mapping tool Google Maps 2014.

The results obtained by means of the photo-interpretation were validated through a series of sample field inspections on the given vineyard area (Fig. 3). Figures 2 and 3 show that

the selected area has wide surfaces of vineyard covered with plastic materials and, thus, huge quantities of plastic materials are generated and need a suitable collection and disposal.



Figure 3 Vineyards and covering materials for crop protection.

CONCLUSIONS

The methodology developed in the present research enabled the localization of the points where huge quantities of agricultural plastic wastes are generated. Land use maps must be integrated with ortophotos in order to obtain complete information. Further development of the research should be addressed to quantify the generated plastic wastes, by using available average plastic consumption values per hectare, in order to design an efficient system of collection and disposal on the territory. The same methodology can be applied to different kinds of agricultural plastic wastes, such as pipes and containers, by relating the average consumption of plastic materials to the cultivated crop.

ACKNOWLEDGEMENTS

The contribution to programming and executing this research must be equally shared between the Authors.

The present research has been carried out under the project “AWARD Agricultural Waste valorisation for a competitive and sustainable Regional Development”, European Territorial Cooperation Programme Greece-Italy 2007-2013, Contract n. I3.11.03.

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WATER DEGRADATION EFFECT ON SOME STARCH-BASED PLASTICS

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SUMMARY

The use of starch resources in order to obtain degradable bioplastics has experienced a great development in the last years, due to environmental problem concerning the plastic waste disposal and reducing of oil resources [3]. The starch represents a possible solution to this challenge, due to its hydrophilic nature, which plays an important role in initiating biodegradation process [1, 4].

Polymer hydrolytic degradation may be defined as the scission of the polymeric chain by the attack of water to form oligomers and finally monomers.

Among the techniques that can be used to obtain information about the degradation mechanism of biopolymer are water uptake and rheological measurements

This paper presents the results of water absorption and rheological investigations for two types of starch-based packaging materials obtained by thermoplastic extrusion of native starch, (with an amylase content of 21%), with different starch, glycerol and water ratios, subjected to natural degradation after absorption of distillate water.

It was observed that the sample containing starch / glycerol / water ratio of 68/17/15 is rapidly degraded -after 8 hours forming a colloidal solution, and sample with a content of 78/19.5/2.5 starch / glycerol / water reaches the limit of swelling after 5 days, after which it begins to decompose slowly.

The rheological measurements for the samples show that at low temperature (30°C) there is a dependence of viscosity function of shear rate which does not comply with the Newtonian model. If the temperature increases further than 60°C the dependence between viscosity and share rate tends to linearity.

Switching from a non-Newtonian behavior to a Newtonian one indicates that the large conglomerates of polymeric structures transforms in smaller elements with spherical symmetry, characteristic of simple Newtonian liquids. It is clear evidence of degradation [5].

Key words: starch based plastics, degradation, rheological measurements

INTRODUCTION

During the last years, the world has witnesses the concern for diminishing the plastic material waste, one of the main means of pollution of water and soil.

Research and development activities conducted worldwide to identify alternative raw materials that can be use to ensure an environmentally –friendly nature of plastics materials revealed starch based biopolymers as a possible solution to the environmental problem concerning the plastic waste disposal and reducing of oil resources [3]. The target of recent investigations in the field of bioplastics is to obtain packaging material from pure starch and to exclude synthetic polymers from the formulation [2].

Native starch exists in a semicrystalline granule and it contains two polysaccharides: amylase and amylopectine. Due to the intra- and intermolecular hydrogen bonds between the hydroxyl groups in starch molecules, the native starches are not thermoplastic compounds, but in the presence of a plasticizer (water, glycerol, sorbitol, etc.), of high temperature (90°-180°C), and subjected to mixing-shearing processes, it melts and becomes fluid, providing possibility of use with extrusion, injection, blowing equipment, similar to those used for synthetic plastic materials.

An important role in initiating biodegradation process of starch is played by its hydrophilic nature, [1, 4]. Polymer hydrolytic degradation may be defined as the scission of the polymeric chain by the attack of water to form oligomers and finally monomers.

A number of non-destructive techniques can be used to obtain informations about the degradation mechanism of biopolymer, like Fourier transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC), nuclear magnetic resonance spectroscopy (NMR), water uptake, rheological measurements, X-ray Diffraction (XRD).

This paper presents the results of water absorption and rheological investigations for two types of starch-based packaging materials obtained by thermoplastic extrusion of native starch, (with an amylase content of 21%), with different starch, glycerol and water ratios, subjected to natural degradation after absorption of distillate water.

METHODS

The normal corn starch used in this study was obtained from SC Amylon SA Sibiu, Romania. The initial water content of starch on wet basis (wt.b) was 10.76% and the density was 0.561 g/cm³. The amylase content was 21%. The glycerol was purchased from SC Nordic Invest SRL Cluj Napoca and had a concentration of 99.5% and a density of 1.262 g/cm³. The water used was from the water supply system. The composition of samples is shown in Table 1. The first point of interest was the observation of the water absorption by the dried samples.

The packages samples were cut into pieces, (the size of 5-10 mm), as shown in Fig.1, and distilled water was added. In Table 2 are indicated the quantities of sample and water used for determining the uptake water.

Table1 The ratio of the components starch-glycerol-water in the used formulas

Sample	Starch [%]	Glycerol [%]	Water [%]
1	78	19.5	2.5
2	68	17	15

Table 2 The quantities of packaging sample and distilled water used for determining the uptake water

Packaging sample	Dry sample [g]	Distilled water [g]	Initial weight of the recipient, sample and water [g]
1	1.21	1.94	21.06
2	0.38	9.50	28.60

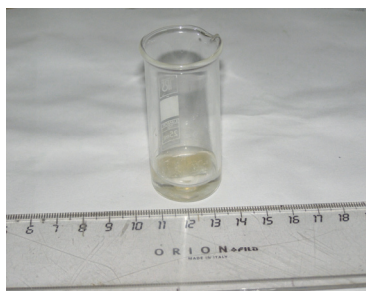


a)

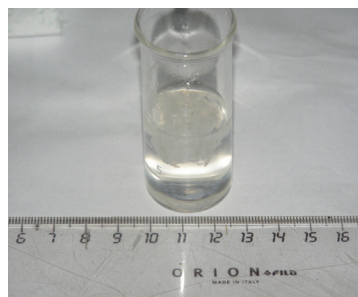


b)

Figure 1 Packaging samples: a)-Sample 1 ;b)- Sample 2



a)



b)

Figure 2 Samples after 40 minutes of swelling: a)-sample 1; b)-sample 2

The quantity of absorbed water was determined as follows. First we measured the mass of samples in dried state, after that the samples were immersed in distilled water and kept 30 minutes. Then the samples were removed from water and the excess water was removed by placing the sample on absorbent paper for 5 minutes and the water uptake was measured using a Partner WLC 0.6/B1 analytical balance with a precision of 0.1 g. After each measurement we refill the water until we reach the initial weight of recipient+sample+water and we repeated this measurement until we obtained more than 5 equal values for the uptake water.

For the rheological measurement we prepare different samples from that used for determining uptake water. The quantities of packaging sample and distilled water used are presented in Table 3.

Table 3 The quantities of packaging sample and distilled water used for rheological measurements

Packaging sample	Dry sample [g]	Distilled water [g]	Initial weight of the recipient, sample and water [g]
1	24.49	39.19	86.11
2	0.80	20.00	48.36

The rheological measurements were performed using the Brookfield DV-III Ultra programmable rheometer with 0.01-250 RPM and precision of $\pm 1,0\%$. To determine the viscosity at different temperatures the samples were heated in TC150SD Brookfield Circulating Bath, with standard digital controller, temperature measuring range between 10-150 °C. Viscosity was measured at 30, 40, 50 and 60 °C for each sample. After each measurement we check the total weight of the sample (container, sample and water) and water lost by evaporation was completed to attain initial weight (Table 3).



Figure 3 Viscosity measurement with Brookfield DV-III Ultra programmable rheometer and the TC150SD Brookfield Circulating Bath

We measure the viscosity after the samples reaches their limit of swelling and was completely decompose. For the sample 1, (content of 78/19.5/2.5 starch / glycerol / water), the completely swelling was observed after five days, and for the sample 2, (containing starch / glycerol / water ratio of 68/17/15), after one day.

RESULTS AND DISCUSSION

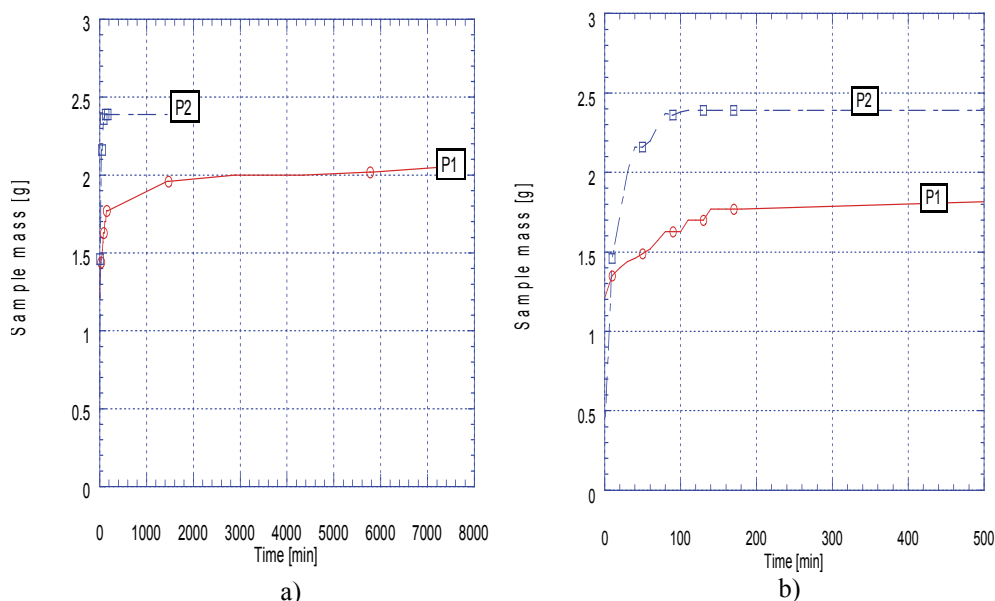


Figure 4 Mass uptake during five days -a; detailed view for the first 8 hours – b; (P1 is the curve for sample 1; P2 is the curve for sample 2)

Figure 4 present the sample mass with uptake water absorbed during five days for the sample 1 (curve P1) and sample 2 (curve P2). Sample 2 which has the formula with lower starch content was degraded after one day. The Sample 1 (with 78/19/2.5 starch/glycerol/water ratio) absorbed lowest quantity of water (~ 60 % of sample's mass in 5 days) with the smallest velocity. The Sample 2 absorbed the highest quantity of water (~ 600% of sample's mass in one day) with a higher velocity, but as we can observe in Fig.4 b, loses its integrity and become a colloid. The water absorption capabilities of the two samples were estimated from water uptake. From this point of view the Sample 2 has a reduced time of degradation while swallowed in water.

Figure 5 present the variation of viscosity for sample P1 (with 78/19/2.5 starch/glycerol/water ratio), at different temperature : 30, 40, 50 and 60 °C and for share rates between 5-200 rot/min. The measurements were performed for the packaging sample degraded in water for five days. The rheological measurements for this sample show that at low temperature (30 °C) the dependence between viscosity and share rate tends to linearity in the

interval 20-200 rot/min when the temperature increases (60 °C) there is a dependence of viscosity function of shear rate which does not comply with the Newtonian model.

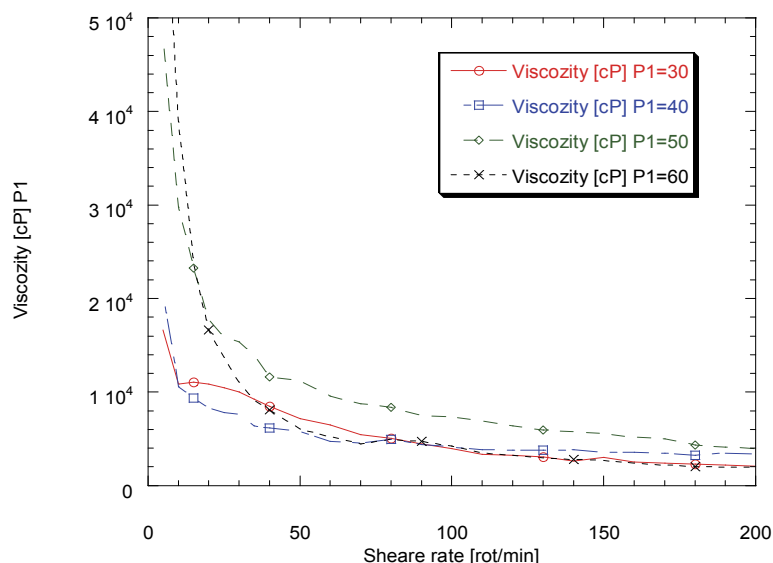


Figure 5 Viscosity variation with temperature and share rate - sample 1 (78/19/2.5 starch/glycerol/water ratio)

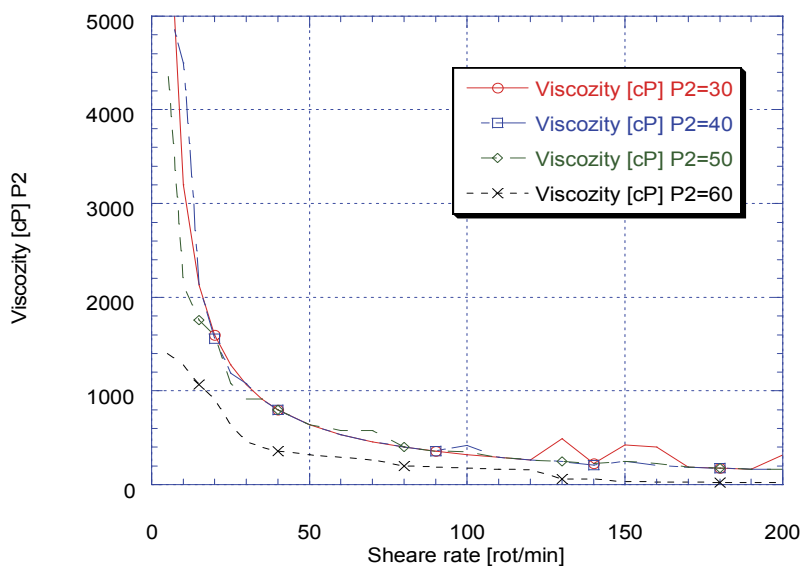


Figure 6 Viscosity variation with temperature and share rate - sample 2 (starch / glycerol / water ratio of 68/17/15)

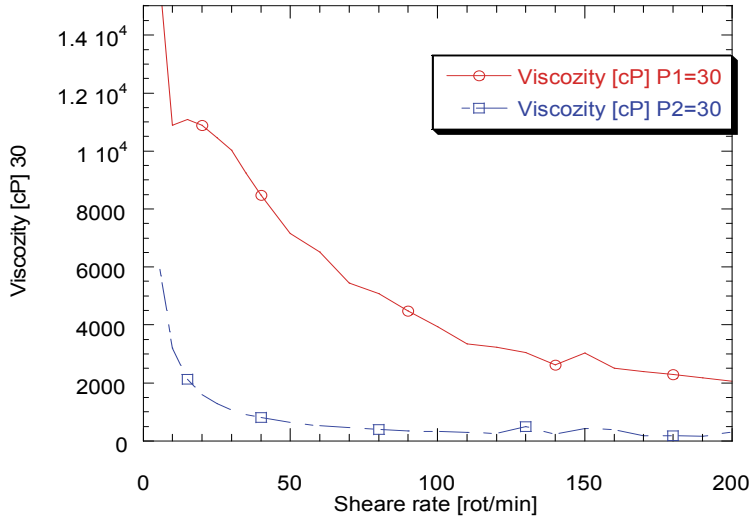


Figure 7 Viscosity variation at 30 °C for the two samples

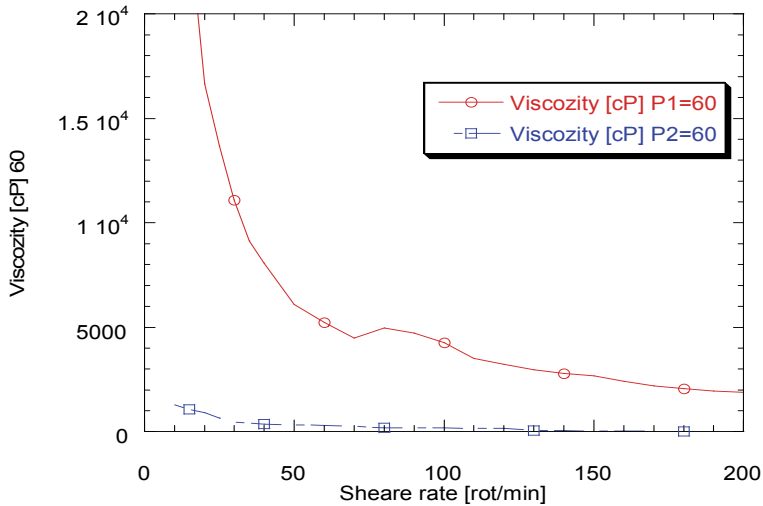


Figure 8 Viscosity variation at 60 °C for the two samples

For the sample 2 (with starch / glycerol / water ratio of 68/17/15) the measurements were performed for the colloidal solution resulted from the degradation of package sample in distilled water (figure 6). The measurement were made in same conditions: at different temperatures : 30, 40, 50 and 60 °C and for share rates between 5-200 rot/min. In this case we observed that that at low temperature (30 °C) the dependence between viscosity and share rate does not comply with the Newtonian model, but if the temperature increases further

than 60°C the dependence between viscosity and share rate tends to linearity in the interval 20-200 rot/min..

Figures 7 and 8 present the viscosity variation for different share rates, at the same temperatures (30° and 60°C). We can observe that for the sample 2 the dependence between viscosity and share rate tends to linearity (more obvious for 60°C) while for sample 1 the dependence between viscosity and share rate does not comply with the Newtonian model.

Switching from a non-Newtonian behavior to a Newtonian one indicates that the large conglomerates of polymeric structures transform in smaller elements with spherical symmetry, characteristic of simple Newtonian liquids. It is clear evidence of degradation [5].

From degradation point of view and viscosity variation point of view it is clear that sample 2, with starch / glycerol / water ratio of 68/17/15 is a better package formula.

CONCLUSIONS

Two packaging samples were tested in order to observe their degradation while swallowed in water. We observed that when the starch/ water ratio decreased the sample becomes more soluble in water. For sample 2 (starch/glycerol/water: 68/17/15) the degradation appears after one day of water immersion, and for sample 1 the degradation process continues slowly in time but from day 5 the sample package starts to decompose.

The rheological measurements for the samples show that for the sample 2 with lower starch content and higher water content of the formula, at higher temperature (60°C), the dependence between viscosity and share rate tends to linearity, while for a lower temperature (30°C) the dependence between viscosity and share rate does not comply with the Newtonian model.

ACKNOWLEDGMENTS

This work was supported by CNCIS –UEFISCDI, project number PN II – IDEI code 284/2011 and 307/2011.

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BIOCHEMICAL QUALITY OF TOMATOES DEPENDING ON GROWING TECHNOLOGY

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SUMMARY

The research aimed to establish the most appropriate culture technological sequences for three varieties of early tomatoes (b1 = Isalnita 29, b2 = Isalnita 50, b3 = Buzau 50) and two varieties of summer-autumn tomatoes (b1 = Buzau 22, b2 = Buzau 1600) in order to obtain high quality fruit with a suitable biochemical content. All tomatoes varieties that were tested benefited in culture for three different density variants (a1 = 20,000 plants/ha, a2 = 40,000 plants/ha, a3 = 60,000 plants/ha) and two levels of fertilization (c1 = N:200 kg/ha; P2O5:100 kg/ha; K2O:100 kg/ha, c2 = N:300 kg/ha; P2O5:200 kg/ha; K2O:100 kg/ha). Immediately after harvesting, certain biochemical analyses were carried out concerning the main components of the fruit: total soluble solids, soluble carbohydrates, total acidity, vitamin C. Results show that the content of tomatoes in major biochemical indicators vary depending on variety, planting density and lightly on fertilizer dose of culture. Among the studied varieties were revealed early tomatoes Isalnita 29 variety, with the highest values of the biochemical analyzed indices (total soluble solids = 7.75%, soluble carbohydrates = 3.78%, total acidity = 0.32%, vitamin C = 29.12 mg/100 g) and summer-autumn tomatoes variety Buzau 22, with a content of 7.77%, 3.32%, 0.57% and 36.63 mg/100 g respectively. As the density is lower, the biochemical indicators have higher values for all five varieties. Between tested fertilization variants, at a level of nutrition below the limits of 300 kg/ha N, 200 kg/ha P2O5 and 100 kg/ha K2O, there are no essential differences in the values of the main chemical components. There was observed a slight decrease in total soluble solids content, acidity and ascorbic acid in case of the c2 variant comparative to c1 variant.

Key words: variety, planting density, level of nutrition, biochemical compounds

INTRODUCTION

Tomatoes are one of the most important vegetable species in our country, due to the fact that they can be consumed both fresh and processed in different ways (Stan et al., 2003).

Tomatoes are healthy and contain very few calories. They have a significant content of vitamin C, minerals (e.g. : potassium) and important micro-nutrients. The rest is made up of water in percent of 95%. Tomatoes help to combat coronary diseases and arteriosclerosis, this fact being due to the lycopene, which is a carotinoid with antioxidant properties (www.vivat-familia.ro, 2013).

Romanian researcher Vinătoru (2006) affirmed that the Romanian tomato is tasteful, aromatic, beneficial for health, being cultivated on natural soil, not forced with chemical substances.

In appreciation of the quality and nutritive-alimentary value of the fruits, is taken into consideration not only the physical and sensory characteristics (size, shape, colour, specific weight, texture firmness, flavor, taste etc.) or technological characteristics (storage capacity, transport and handling resistance, presence of diseases or pests attack, remanence of pesticides), but also is taken into consideration the biochemical properties: water content, dry matter, carbohydrates, acids, cellulose, vitamins, pigments, mineral salts (Salunkhe and Kadam, 1998).

The complexity of growing and maturation phenomenon includes successive biochemical reactions that result in accumulation of different carbohydrates, organic acids and vitamins in characteristic proportions for the species and variety, as well as their use in metabolic processes (Alexe, 2013).

The chemical composition of tomatoes depends on the soil chemistry (Neata, 2002.; Anton et al., 2011; Cioroianu et al., 2010; Cioroianu et al., 2011) and on the culture technology.

The biochemical modifications that take place in fruits are characterized by intensive and continuous conversions, which is why they should be analyzed in a close interdependence with the action of environmental factors, in order to specify optimal conditions that determine superior quality of the products, a good storage capacity and minimum changes of the chemical composition of the products after harvesting.

This paper presents some aspects regarding the influence of variety, planting density and fertilization of tomato culture upon the biochemical compounds level in fruits.

MATERIAL AND METHODS

The researches were conducted during period 2013-2014, using romanian varieties of early tomatoes and summer-autumn tomatoes, obtained in a vegetable farm located in an area of the Romanian seaside.

The trial was organized as a trifactorial experience, with following experimental factors:

A – planting density (plants/ha)	B – variety		C – fertilization level
	early tomatoes	summer-autumn tomatoes	
a1 – 20,000	b1 - Isalnita 29 (Figure 1)	b1 – Buzau 2 (Figure 4)	c1 – N:200 kg/ha; P ₂ O ₅ :100 kg/ha; K ₂ O:100 kg/ha
a2 – 40,000	b2 - Isalnita 50 (Figure 2)	b2 – Buzau 1600 (Figure 5)	c2 – N:300 kg/ha; P ₂ O ₅ :200 kg/ha; K ₂ O:100 kg/ha
a3 – 60,000	b3 - Buzau 50 (Figure 3)		



Fig 1 Early tomatoes variety Isalnita 29



Fig 2 Early tomatoes variety Isalnita 50



Fig 3 Early tomatoes variety Buzau 50



Fig. 4 Summer-autumn tomatoes variety Buzau 22



Fig. 5 Summer-autumn tomatoes variety Buzau 1600

The observations and determinations regarding biochemical composition were made at Research and Development Institute for Processing and Marketing of the Horticultural Products - Horting Bucharest

The main chemical components of the fruit were determined, as following: total soluble solids, using an ABBE refractometer, soluble carbohydrates, by Bertrand titrimetric method total acidity and ascorbic acid by the titrimetric method.

RESULTS AND DISSCUSION

Early tomatoes

The fruits from early tomatoes varieties are characterized by a high content in total soluble solids, soluble carbohydrates and vitamin C (Table 1).

Table 1 The influence of variety upon chemical composition of early tomatoes

Planting density	Variant	Total soluble solids %	Soluble carbohydrates %	Total acidity % citric acid	Vitamin C mg/100g
b1	a1c1	7.8	3.64	0.39	29.75
	a2c1	8.0	3.95	0.35	28.60
	a3c1	8.0	3.89	0.31	31.15
	b1c2	8.3	4.17	0.26	25.40
	a2c2	7.5	3.61	0.29	27.40
	a3c2	6.9	3.43	0.31	32.40
	average	7.75	3.78	0.32	29.12
b2	a1c1	7.0	3.05	0.28	29.08
	b2c1	6.5	2.49	0.28	26.50
	a3c1	7.3	2.89	0.29	26.35
	a1c2	6.5	2.61	0.26	25.03
	a2c2	5.9	2.43	0.27	29.90
	a3c2	5.90	2.40	0.24	27.30
	average	6.66	2.77	0.28	27.73
b3	a1c1	5.7	2.32	0.27	29.15
	a2c1	5.9	2.65	0.33	26.50
	a3c1	5.8	2.61	0.24	25.60
	a1c2	6.0	2.92	0.30	30.40
	a2c2	5.5	2.40	0.24	29.90
	a3c2	4.9	2.73	0,27	27.40
	average	5.63	2.60	0.28	26.15

The average value total soluble solids surpassed at all varieties the value of 5.55%, which allow us to include these varieties in the group of tomatoes with high nutritional

value. The highest amount total *soluble solids* is present at variety Isalnita 29, who reached the value of 7.75% at the average of varieties. This variety is also distinguished by the highest soluble carbohydrates content (3.78%). Total acidity content had average values very closed between varieties, of 0.32% citric acid at variety Isalnita 29, of 0.27% at variety Isalnita 50 and the value of 0.28% at variety Buzau 50. Vitamin C content, which, as same as total soluble solids and soluble carbohydrates varies depending on variety, was on average of 29.12 mg/100g at variety Isalnita 29, 26.47 mg/100 g at variety Isalnita 50 and 27.73 at variety Buzau 50.

The results presented in Table 2 show that the planting density is also influencing the chemical composition of fruits. The total soluble solids content is higher at a lower planting density.

Table 2 The influence of planting density upon chemical composition of early tomatoes

Planting density	Variant	Total soluble solids %	Soluble carbohydrates %	Total acidity % citric acid	Vitamin C mg/100g
a1	b1c1	7.40	3.64	0.39	28.75
	b2c1	7.20	3.35	0.28	25.30
	b3c1	7.10	3.32	0.27	27.08
	b1c2	7.30	3.71	0.26	28.23
	b2c2	7.20	3.17	0.29	26.35
	b3c2	7.00	2.92	0.30	27.30
	average	7.20	3.35	0.29	27.16
a2	b1c1	6.50	2.95	0.35	26.60
	b2c1	6.90	2.49	0.28	25.75
	b3c1	6.50	2.65	0.33	29.90
	b1c2	6.20	2.61	0.29	25.10
	b2c2	6.00	2.43	0.26	25.03
	b3c2	5.90	2.40	0.24	27.30
	average	6.33	2.58	0.29	26.66
a3	b1c1	6.20	2.49	0.31	29.15
	b2c1	5.90	2.23	0.29	26.50
	b3c1	5.40	2.01	0.24	25.60
	b1c2	5.90	2.43	0.31	30.40
	b2c2	5.40	2.21	0.27	29.90
	b3c2	5.20	2.03	0.27	27.40
	average	5.66	2.23	0.28	26.15

At a planting density of 20,000 plants/ha total soluble solids had the average value of 7.20%, while at a planting density of 60,000 plants/ha, this was only 5.66%.

Soluble carbohydrates decreased from the value of 3.35% at variant a1 to 2.58% and respectively at 2.23% in case of variants a2 and a3 respectively Carbohydrates content is, as same as total soluble solids, a variety distinctiveness.

Vitamin C content was less influenced by planting density. However, variant a1 presented a slight increased content of ascorbic acid (27.16 mg/100g) comparatively with variant a2 (26.66 mg/100g) and variant a3 (26.15 mg/100g).

The results presented in Table 3 highlight the fact that between tested fertilization variants, there are no essential differences regarding the values of main chemical components. It is observed a slight decrease in total soluble solids values, acidity and ascorbic acid in variant c2 comparative to variant c1.

Table 3 The influence of fertilization level upon chemical composition of early tomatoes

Fertilization level	Variant	Total soluble solids %	Soluble carbohydrates %	Total acidity % citric acid	Vitamin C mg/100g
c1	a1b1	6.80	2.64	0.39	27.75
	a1b2	7.00	3.05	0.28	25.30
	a1b3	6.70	2.32	0.27	29.08
	a2b1	7.00	2.95	0.35	26.60
	a2b2	6.50	2.49	0.28	25.75
	a2b3	6.90	2.65	0.33	29.70
	a3b1	7.00	2.89	0.31	29.15
	a3b2	6,90	2.70	0.29	26.50
	a3b3	6.80	2.61	0.24	25.60
	average	6.84	2.70	0.31	27.27
c2	a1b1	7.30	3.17	0.26	23.40
	a1b2	6,90	2.71	0.29	26.35
	a1b3	7.00	2.92	0.30	27.30
	a2b1	6.50	2.61	0.29	25.40
	a2b2	6.20	2.43	0.26	25.03
	a2b3	6.00	2.40	0.24	27.30
	a3b1	6,90	2.43	0.31	30.40
	a3b2	6.40	2.90	0.27	29.90
	a3b3	5.70	2.73	0.27	27.40
	average	6.54	2.71	0.27	26.94

Results concerning the interaction of factors A x B x C shows that the fertilization acts independently of variety and planting density, but in both variants, variant c1 and variant c2, the higher content in total soluble solids (7.00%, respectively 7.30%) soluble carbohydrates (3.50%, respectively 3.17%), total acidity (0.39% respectively 0.31% citric acid) and vitamin C (29,70 mg/100g, respectively 30.40 mg/100g) was recorded at variant a1b1 (a1:planting density=20,000l/ha; b1:variety Isalnita 29), proving the influence of variety and planting density (Fig. 6).

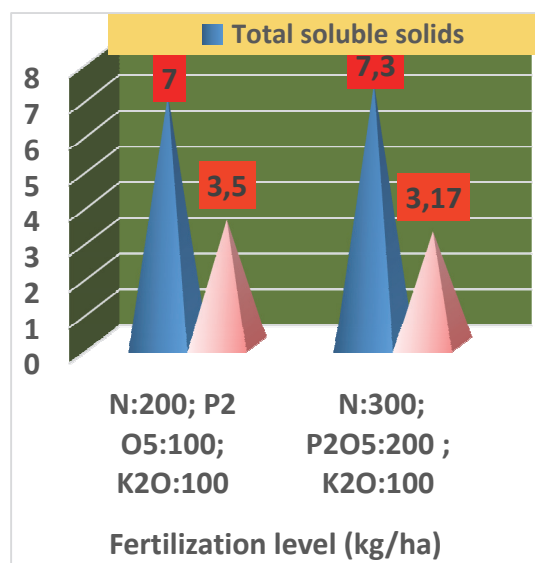


Figure 6 The influence of interaction of the factors variety (Isalnita 29), planting density (20,000 pl/ha) and fertilization level upon total soluble solids and soluble carbohydrates content of early tomatoes

The data analysis presented in Table 4 shows that both varieties of summer-autumn tomatoes have a high nutritional value due to the chemical composition of fruits. Although, between the 2 varieties, the fruits of variety Buzau 22 are richly in the main biochemical components than the fruits of variety Buzau 1600.

Therefore, the total soluble solids content is on average of 7.80% at variety Buzau 22 and 7.18% at variety Buzau 1600, the content of soluble carbohydrates is 3.32% beside 3.09%, and ascorbic acid content is 36.30 mg/100g beside 33.18mg/100g.

Regarding the influence of planting density, as same as early tomatoes, as the density is lower, the biochemical indicators have higher values (Table 5).

At a planting density of 20, 000 plants/ha, tomatoes accumulated on average 7.92% total soluble solids, 3.48% soluble carbohydrates, 0.59% citric acid and 36.87 mg/100 g vitamin C. At a planting density of 60,000 plants/ha, these values were: 7.22%, 3.12%, 0.50% and 33.0 mg/100g respectively.

Table 4 The influence of variety upon chemical composition of summer-autumn tomatoes

Variety	Variant	Total soluble solids %	Soluble carbohydrates %	Total acidity % citric acid	Vitamin C mg/100g
b1	a1c1	7.70	3.45	0.60	37.50
	a2c1	7.40	3.10	0.75	36.40
	a3c1	7.30	3.11	0.55	40.30
	a1c2	8.30	3.45	0.63	35.60
	a2c2	8.20	3.55	0.60	34.70
	a3c2	7.70	3.29	0.51	33.50
	average	7.80	3.32	0.57	36.33
b2	a1c1	7.10	2.93	0.56	34.80
	a2c1	7.00	3.05	0.53	14.10
	a3c1	6.90	3.01	0.53	32.40
	a1c2	7.60	3.19	0.58	34.90
	a2c2	7.50	3.27	0.57	32.40
	a3c2	7.00	3.07	0.43	30.50
	average	7.18	3.09	0.53	33.18

Table 5 The influence of planting density upon chemical composition of summer-autumn tomatoes

Planting density	Variant	Total soluble solids %	Soluble carbohydrates %	Total acidity % citric acid	Vitamin C mg/100g
a1	b1c1	7.70	3.45	0.60	37.50
	b2c1	8.10	3.93	0.56	34.80
	b1c2	7.60	3.35	0.63	40.30
	b2c2	8.30	3.19	0.58	34.90
	average	7.92	3.48	0.59	36.87
a2	b1c1	7.30	3.10	0.57	36.40
	b2c1	7.00	3.05	0.53	34.10
	b1c2	8.20	3.55	0.60	34.70
	b2c2	7.50	3.27	0.57	32.40
	average	7.50	3.24	0.54	34.40
a3	b1c1	7.30	3.11	0.55	35.60
	b2c1	6.90	3.01	0.53	32.40
	b1c2	7.70	3.29	0.51	33.5
	b2c2	7.00	3.07	0.43	38.50
	average	7.22	3.12	0.50	33.00

At a different fertilization level, the content of main biochemical constituents follows the same direction as early tomatoes (Table 6).

Table 6 The influence of fertilization level upon chemical composition of summer-autumn tomatoes

Fertilization level	Variant	Total soluble solids %	Soluble carbohydrates %	Total acidity % citric acid	Vitamin C mg/100g
c1	a1b1	8.30	3.45	0.60	37.50
	a1b2	7.60	3.19	0.56	34.80
	a2b1	7.20	3.55	0.57	36.40
	a2b2	7.50	3.27	0.53	34.10
	a3b1	7.1	3.29	0.55	35.60
	a3b2	7.00	3.07	0.53	32.40
	average	7.45	3.30	0.56	35.10
c2	a1b1	7.70	3.45	0.63	40.30
	a1b2	7.10	2.93	0.58	34.90
	a2b1	7.30	3.10	0.60	34.70
	a2b2	7.00	3.05	0.57	32.40
	a3b1	7.30	3.11	0.51	33.50
	a3b2	6.90	3.01	0.43	30.50
	average	7.21	3.11	0.55	34.40

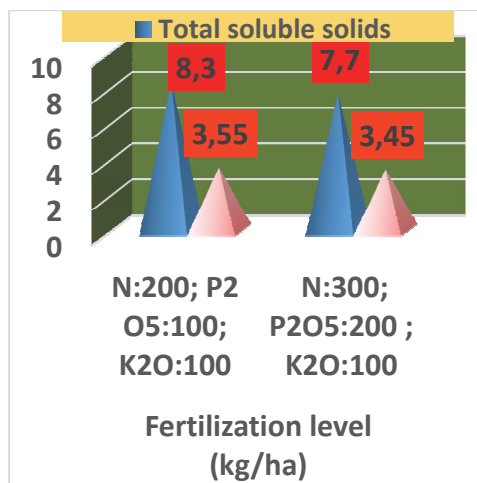


Figure 7 The influence of interaction of the factors variety (Buzau 22), planting density (20,000 pl/ha) and fertilization level upon total soluble solids and soluble carbohydrates content of summer-autumn tomatoes

As same as early tomatoes, in both variants, variant c1 and variant c2, the higher content in total soluble solids (8.30%, respectively 7.70%) soluble carbohydrates (3.55%, respectively 3.45%), total acidity (0.60% respectively 0.63% citric acid) and vitamin C (37.50 mg/100g, respectively 40.30 mg/100g) was recorded at variant a1b1 (a1:planting density=20,000 pl/ha; b1:variety Buzau 22), also proving the influence of variety and planting density (Fig. 7).

CONCLUSIONS

- The content of tomatoes fruits in the main biochemical indicators total soluble solids, soluble carbohydrates, organic acids, vitamin C) varies depending on variety and culture technology conditions.
- Between the five varieties that were studied, the variety of early tomatoes Isalnita 29 and summer-autumn tomatoes Buzau 22 are distinguished through higher soluble total soluble solids t (7.75%, respectively 7.80%), soluble carbohydrates (3.78%, respectively 3.32%) organic acids (0.32%, respectively 0.57% citric acid) and vitamin C (29.12 mg/100 g, respectively 36.33 mg/100 g).
- Regarding the influence of planting density, as same as early tomatoes and summer-autumn tomatoes, as the density is lower, the biochemical indicators have higher values. From the biochemical point of view, the tomatoes that came from culture with plantig density of 20, 000 plants/hectares recorded the best results.
- In the case of different fertilization level, at a nutritional level below the limits of 300 kg/ha N, 200 kg/ha P₂O₅ and 100 kg/ha K₂O, there are no essential differences in the values of the main chemical components. It is observed a slight decrease of values in soluble dry matter content, acidity and ascorbic acid in case of variant c2 (300 kg/ha N, 200 kg/ha P₂O₅ and 100 kg/ha K₂O) comparative to variant c1 (200 kg/ha N, 100 kg/ha P₂O₅ si 100 kg/ha K₂O).

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QUALITY OF PROCESSED PRODUCTS OF SOME CHERRY VARIETIES

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SUMMARY

Sour cherry trees are cultivated for their fruits that are rich in dietetic and nutritional elements and which are consumed in high quantities both as fresh as well as processed. This paper presents five sour cherry varieties, provided from experimental plots of Research Station for Fruit Growing Constanta, cultivated on large surfaces in our country: Morela, Nana, Pitic, Ilva and Nefris. The fruits were processed as stewed, comfiture (sweetness) and jelly. The sensory analysis of the products were carried out in accordance to STAS 12656-88, which establishes the analysis methods by means of unitary scales (method A), which are used in the appreciation of the organoleptic characteristics of alimentary products. These methods are applied in order to evaluate an ensemble of organoleptic features, such as the aspect, the colour, the taste, the texture and, if necessary, the consistence. Observations, measurements and determinations were carried out in order to establish the fruit quality and the readiness for processing. For every variety it was established the first option for its adequacy for being processed as stewed fruit, comfiture and jelly. The obtained results reveal the fact that variety Morela is the best: the quality of the fruit is high, with a very good readiness for processing into all the products: stewed fruit, comfiture and jelly.

Key words: stewed fruit, comfiture, jelly, sensory analysis

INTRODUCTION

Sour cherry fruits are very appreciated for being consumed fresh, for the diversity of culinary preparations or pastry. From sour cherries are made juices, comfiture, stewed fruit, jam, cherry brandy, syrup, jelly, as well as multiple products: ice cream, sorbet, soufflé. For

comfiture, stewed fruit and jelly are preferred sour cherry varieties with fleshy pulp and intense colored juice [9].

Cherries have a beneficial effect on human body by adjusting the acid-base balance, by improving blood's composition and also in renal, hepatic and cardiovascular diseases, etc. They are considered to be dietetic fruits because of their complex chemical composition: 13,9-23,2% *total soluble solids*, 5-19,4 mg% carbohydrates, 0,9-1,9 mg% organic acids, 0,8-1, 1 mg% proteins, 0,1-0,4 mg% pectin, 0,12-2,35 mg% tannoid substances, a range of mineral ions (potassium, phosphorus, calcium, magnesium), vitamins PP, E, B1, B2, carotene, folic acid, etc [6]. Sour cherry tree is a rustic species that succeeds in all culture areas from the country, being also a very good melliferous species [15].

Cherry fruits are perishable and they do not improve their quality after harvest.

They matures relatively echeloned in the tree and it is necessary the harvesting in 2 or 3 passes in order to obtain a good quality fruits [1, 2, 5].

The aim of this paper is to evaluate the suitability for processing as stewed fruit, comfiture and jelly of some sour cherry varieties cultivated in Romania.

MATERIAL AND METHOD

The researches were carried out in years 2013 and 2014, using 5 sour cherry varieties: Morela, Nana, Pitic, Ilva and Nefris, cultivated in experimental plots at Research Station for Fruit Growing Constanta, which were described from the point of view of the tree vigor, disease-resistant, maturation period. Immediately after harvesting, the fruits were examined organoleptically to estimate the appearance (size, shape, colour), the dimension of stone, the taste and the fruit firmness. It was also determined the content of total soluble solids (by refractometer method) and total acidity (by titrimetric method).

The organoleptic quality appreciation of fresh fruits was conducted by performing sensory testing fruit, and it was used an evaluation method with scoring scale from 1 to 100. There were used tasting sheets with three criteria of appreciation (appearance, firmness, taste). Depending on the score achieved, five quality classes were defined: very good (80-100), good (60-79), acceptable (40-59), moderate (20-39) and inappropriate (0-19).

The fruits were processed as stewed fruit, comfiture and jelly at Research and Development Institute for Processing and Marketing of the Horticultural Products – Bucharest, in the micro-production laboratory. The packaging was made in glass jars with a capacity of 720 milliliters for stewed fruits and 370 milliliters for comfiture and jelly, with twist-off closing. The sensory analysis of processed products was made according to STAS 12656-88, that establishes the analysis methods with unitary scoring scales (method A), used for the evaluation of organoleptic characteristics of alimentary products. These methods are applied for the appreciation of a set of organoleptic properties: appearance, colour, taste, texture or the consistence. The evaluation of each organoleptic characteristic was made by comparison with scoring scales from 0 to 5 points and it was obtained an average score given by the group of tasters on the basis of registration of awarded points on individual sheets. It was made the calculation of the weighted average of the scores, and totalize them

for obtaining total average score and there were settled organoleptic characteristics of the products based on the principle of total average, by comparison with a scale from 0-20 points. Finally, there were given scores for each variety.

Within the overall score achieved by the different analyzed products, there were established five quality classes: very good (18.1-20.0), good (15.1-18.0), satisfactory (11.1-15.0), unsatisfactory (7.1-11.0) and improperly (0 -7.0). Sensory analysis of preserved products has been carried out after a period of not less than 21 days after processing (in which it is considered that the product stabilizes).

RESULTS

Variety Nana, presented in Figure 1 is self-fertile, of Romanian origin, obtained at Research Station for Fruit Growing Baneasa by open pollination of variety Crisana. The tree, of reduced vigor, starts early bearing fruit and produces well every year. The average production in second year of bearing fruit is of 20 kilograms/tree. Fully ripens in the second decade of June. The fruit is medium sized, spherical, coloured in dark red, red-pink pulp, is consistent, appropriate astringency (sour-sweet), juicy, medium-sized stone, appreciated for processing and fresh consumption. This variety is disease-resistant, especially to *Cocomyces hiemalis*.



Fig.1 Sour cherries, variety *Nana* (www.pomicolaiasi.ro)



Fig. 2 Variety *Pitic* (www.pomicolaiasi.ro)

The variety Pitic (Figure 2), self-fertile, with very late flowering, is of Romanian origin, obtained at Research Station for Fruit Growing Iasi. The tree has reduced vigor, fructifies abundant and constantly. The fruit is medium-sized, spherical-elongated shaped, dark burgundy peel. The pulp is red, soft, with intensely colored juice. The taste is acidulous, tannic even at over-ripening, and the stone is relatively big. The ripening period is very late, the end of July-early August, being the latest variety among the current range. It has a good resistance to cold hardiness and drought, and medium resistance to anthracnose and fruit rot.

The self-fertile variety Nefris (Figure 3) is a sour cherry tree of Polish origin, recently introduced in culture, that matures in the second decade of July. The tree is of middle-small vigor, with flat-shaped fruiting branches, productive (18,5 kg/tree in the third year of bearing fruits). The fruit is medium to large sized, in dark burgundy colour, intensely colored juice, suitable for industrialization.



Fig. 3 Variety *Nefris* (www.pomicolaiasi.ro)

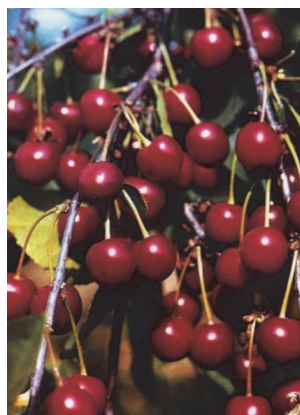


Fig. 4 Variety *Morela* (www.pomicolaiasi.ro)

The variety Morela (Figure 4) has a medium vigor, is self-fertile, yields regularly, bears fruits on shoots. The fruit is large, spherical, dark burgundy, purple red pulp, red juice. It is well suited for industrialization. It matures in late June.

Variety Ilva (Figure 5) is also self-fertile, the tree is of medium vigor, with globulous canopy, presents tolerance to *Monilinia laxa* and anthracnose (*Blumeriella jaapii*). Because of its reduced height it is recommended for intensive orchards. The fruit is medium to large sized, spherical, dark-red colour, shiny peel. The pulp is red, with firm texture, not adhering to the stone, juicy, with sweet and slightly sour taste, which is well suited for industrialization. The ripening period is the second decade of June.



Fig. 5 Variety Ilva (www.pomicolaiasi.ro)

The results relating to the fruits and stones size, the content in total soluble solids and acidity and also organoleptic appreciation of fresh fruits are presented in Table 1.

Table 1 The main physico-chemical characteristics and organoleptic appreciation of fresh fruit

Specification	M.U.	VARIETY				
		Nana	Nefris	Ilva	Pitic	Morela
Fruit weight	g	4.07	5.32	4.88	4.76	5.46
Stone percent	%	7.38	4.76	6.79	8.34	5.86
Total soluble solids	%	11.80	11.50	13.60	12.13	13.02
Total acidity	%	1.17	1.31	0.88	1.44	0.98
Total average score	points	82.41	79.03	96.82	71.70	89.39
Score	-	very good	good	very good	good	very good

The analysis of data presented in Table 1 shows that the average weight of the five varieties of fruit is medium, medium to large or large, varying from 4.07 g (variety Nana) and 5.46 g (variety Morela).

The stones size and especially the proportion between fruit weight and stone weight has a great importance, particularly for industrialization, in order to obtain a good processing efficiency. In the case of studied varieties, the stone percentage of the fruit weight is between 4.76% at variety Nefris and 8.34% at variety Pitic.

The average value of tota soluble solids content in fruits, in the conditions of years 2013-2014 is quite low, oscillating between 11.50% at variety Nefris and 13.60% at variety Ilva.

The total acidity in fruits is the indicatory that confers the balance of their taste. From the table analysis it is observed that the value of acidity is between 0.88% at variety Ilva and 1.44% at variety Pitic.

The sensory analysis of fresh fruits (Figure 6) highlights the variety Ilva, with an average total score of 96.82, which, along with the varieties Morela (89.39 points) and Nana (82.41 points) obtained the score "very good". The varieties Nefris (79.03 points) and Pitic (71.70 points) obtained the score "good".

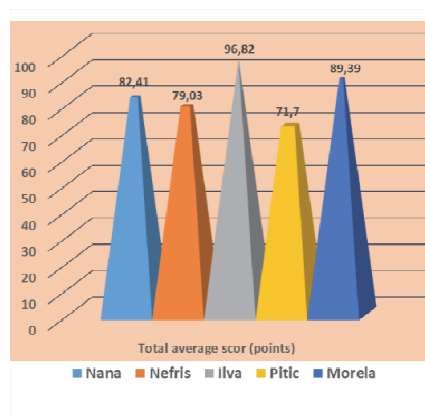


Fig. 6 The sensory analysis of fresh fruits

The processing of fruit as stewed

Stewed fruits are tinned food obtained from fruits in sugar syrup, packaged in hermetically sealed recipients and thermic sterilized. Stewed sour cherries must have a minimum content of 50% fruits and 23% total soluble solids [3, 4, 14]. The short preparation process (65 minutes) gives the possibility to keep in the final product of maximum nutrients, taste properties, colour and flavour [6]. These are the products with the highest exigency to the quality of raw materials, therefore are choosed fruits varieties with certain technological properties and chemical composition, with diffrent ripening periods – from extra-early to tardive - in order to extend the processing season. The fruits are harvested shortly before the ripeness consumption, when the pulp is firm and the flavour is already pronounced [7].

The quality of stewed fruits depends on the properties of variety, whose fruits must be uniform, with attractive colour and good firmness, resistant to sterilization process [8, 10].

In Figure 7 is presented an insight over stewed fruit jars provided from the 5 analyzed varieties.



Fig. 7 Cherry stewed fruit

The results of sensory analysis of the product Stewed sour cherries are presented in Table 2.

Table 2 Sensorial analysis of the product ” Cherry stewed”

Specification	VARIETY				
	Nana	Nefris	Ilva	Pitic	Morela
Appearance	3.46	4.00	3.46	4.82	3.90
Colour	4.43	4.00	3.73	3.64	3.90
Taste	3.20	5.72	5.46	5.66	5.86
Texture	5.54	5.86	5.33	5.86	5.46
Total average score	16.63	19.58	17.98	18.80	19.12
Score	good	very good	good	very good	very good

It is observed (Figure 8) that the best values were obtained at variety Nefris, which was remarked by a distinct taste and very good texture and whom was given an average total score of 19.58. This variety, together with the varieties Morela (19.12 points) and Pitic (18.80 points) obtained the score ”very good”. The varieties Ilva (17.98 points) and Nana (16.63 points), with less pleasant aspect and taste, obtained the score ”good”.

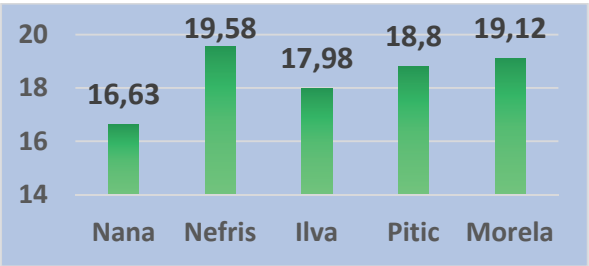


Fig. 8 Total average score of cherry stewed

Processing of fruits as comfiture

Comfiture is a product obtained by boiling and concentration of the fruits in sugar syrup, packaged in hermetically sealed recipients and pasteurized. According to STAS 3750-90, sour cherry comfiture must contain 45-55% fruits, 72% total soluble solids and 0.7% total acidity (expressed by malic acid).

In Figure 9 is presented an insight over comfiture jars provided from the 5 analyzed varieties.



Fig. 9 Cherry comfiture

From the sensory analysis of the product Sour cherry comfiture (Figure 9), it is remarked variety Ilva, with pleasant taste (5.72 points) and a total average score of 19.53 points and also varieties Morela (total average score = 18,86 points) and Nana (total average score = 18,46 points), all three varieties receiving the score "very good" (Table 3).

Table 3 Sensorial analysis of the product "Cherry comfiture"

Specification	Variety				
	Nana	Nefris	Ilva	Pitic	Morela
Appearance	3.90	3.20	4.45	3.53	3.90
Colour	5.86	4.63	5.46	5.31	5.86
Taste	5.06	4.63	5.72	3.26	5.46
Consistence	3.64	2.97	3.90	3.81	3.64
Total average score	18.46	15.43	19.53	15.91	18.86
Score	Very good	good	Very good	good	Very good

Varieties Pitic (total average score =15.91) and Nefris (total average score =15,43) obtained the score "good".

The processing of fruits as jelly

Fruit jelly is obtained from the juices of fresh or preserved fruits, mixed with sugar, pectin and alimentary acids, packaged in hermetically sealed recipients and pasteurized. SP 24-96 (Professional Standard) provides that the sour cherry jellies must contain 67% total soluble solids and 0.7% total acidity (expressed by malic acid). The aspect is of jellyfied mass, transparent, with a slight opalescence (Figure 10).



Fig. 10 Sour cherry jelly

For the product Sour cherry jelly, three of studied varieties (Morela – 20.00 points, Pitic - 19.52 points and Nana – 18.50 points) received the score "very good" (Table 4).

On the firs place is situated variety Pitic, which presents an uniform colour, characteristic of the fruit, and very pleasant sweet - sour taste, for which it received the maximum score. Varieties Nefris and Nana obtained the score "good", with a total average score of 17.40 points, respectively 16.60 points.

Table 4 Sensorial analysis of the product "Cherry jelly"

Specification	VARIETY				
	Nana	Nefris	Ilva	Pitic	Morela
Appearance	5.72	5.86	3.74	5.76	6.00
Colour	3.73	3.73	3.46	5.76	6.00
Taste	3.73	3.55	5.59	4.00	4.00
Consistence	5.32	4.26	3.81	4.00	4.00
Total average score	18.50	17.40	16.60	19.52	20.00
Score	Very good	good	good	Very good	Very goo

After the results obtained in industrial processing of the sour cherries, there were established the destinations of valorization in processed form of the sudied varieties (Table 5).

Table 5 The destinations of valorization in processed form of sour cherry varieties

Variety	Option I	Option II
Nana	comfiture, jelly	stewed fruits
Nefris	stewed fruits	jelly, comfiture
Ilva	comfiture	stewed fruits, jelly
Pitic	jelly, stewed fruits	comfiture
Morela	jelly, stewed fruits, comfiture	-

CONCLUSIONS

Sour cherry varieties that are very appreciated for the consumption as fresh fruits are Ilva (96.82 points), Morela (89.39 points) and Nana (82.41 points).

After the analysis were effectuated and the score that was obtained in the case of processing as stewed fruits, very good results were recorded at varieties Nefris, which was remarked by a distinct taste and very good texture (total average score = 19.58), Morela (19.12 points) and Pitic (18,80 points).

For obtaining the tinned food in the form of comfiture, very suitable are the varieties: Ilva, Morela and Nana, which obtained, after organoleptic tests, 19.53 points, 18.86 points and respectively 18.46 points.

The variety Morela is distinguished by a very good suitability of fruit processing as jelly, the resulted product presenting remarkable sensorial qualities, for which it received the maximum score (20 points). In the same category, with a very good suitability, are included the varieties Pitic (19.52 points) and Nana (18.50 points).

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TECHNOLOGY OF POTATO WEED MANAGEMENT UNDER CONDITIONS OF LOW INPUT SYSTEMS

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SUMMARY

Between years 2011 and 2013 field trials were established with potatoes involving various variants of herbicide applications using recommended rates and 50 % reduced rates. The research was done in 3 replications using de-stoning technology and the early ware potato variety Dali was involved. The aim was to determine, whether low input system could be applied in de-stoning technology for potato growing and whether recommended rate of herbicide could be 50 % reduced while maintaining required level of weed control effect and the same yielding level. The trials show that 50 % reduction of herbicide rate did not have an effect on potato yield. Weed control efficiency, measured toward the end of vegetation, was not reduced in the first trial year due to variants with reduced herbicide rate; in following two trial years the efficiency was 8-12 % reduced. However, this reduction was not expressed in potato yields. The reason is that efficiency reduction did not reach threshold of harmfulness of weed species. Significant differences in potato yields were not found between variants, except for the variant without treatment.

From research standpoint reduced herbicide application could be recommended.

Key words: potato, weed, herbicide, low input technology

INTRODUCTION

Herbicides contribute with more than 45 % to total pesticide consumption worldwide. In potato growing the highest consumption is recorded for fungicides; however, herbicides also play an important role in total consumption of agrochemicals there. Potatoes are crop, in those herbicides could be replaced by mechanical cultivation, but in large-scale production technologies it is increasingly more complicated. Mechanical cultivation depends on weather progress and mechanical treatment of the whole area under relative

favourable conditions is demanding as regard as organization in agricultural enterprises with more than 100 hectares. In the Czech Republic, potato growing technology had been exposed to a substantial change at the turn of 1990s. De-stoning technology has been used almost on areas of agricultural enterprises, where no cultural practices could be performed.

Under these conditions it is difficult to apply principles of integrated weed management using other than chemical methods. The potential solution is use Low input farming system. Low input farming systems "seek to optimize the management and use of internal production inputs (i.e. on-farm resources)... and to minimize the use of production inputs (i.e. off-farm resources), such as purchased fertilizers and pesticides, wherever and whenever feasible and practicable, to lower production costs, to avoid pollution of surface and groundwater, to reduce pesticide residues in food, to reduce a farmer's overall risk, and to increase both short- and long-term farm profitability" (Parr et al. 1990). Application of low input system, where reduced pesticide rates are applied, could contribute to environment protection. For weed management in potatoes many factors are important, especially weather progress, weed species range and weed infestation intensity. In literature, combinations are often mentioned of soil preparation and herbicide rate reduction.

From the literature it is apparent that application of reduced herbicide rates is usually accompanied with yield reduction.

Bellinder et al. (1996) studied time of hilling (4, 5 or 6 weeks after planting; WAP) and 0,5x, 1x, and split (0,5x + 0,5x) rates of metolachlor + metribuzin in conventional tillage (CT) and rye-stubble, reduced tillage (RT). Weed populations 4 to 10 WAP were generally higher in CT than in RT. Weed control with 0,5x rates of metolachlor + metribuzin applied 7 DAH (days after hilling), when hilled 4 and 5 WAP, was equivalent to the 1x and split-rate treatments. Weed control was reduced only when hilling was delayed to 6 WAP and 0,5x of metolachlor + metribuzin applied 7 DAH. Total yields were not influenced by tillage, hilling, or herbicide treatment.

Wallace et al. (1990) applied recommended herbicide doses (Linuron, metribuzin oryzalin and metolachlor) and two-thirds rates to evaluate control of *Amaranthus retroflexus* and *Chenopodium album* in conventional and rye-stubble reduced-tillage potato production systems. Regardless of tillage, *Chenopodium album* control was satisfactory during both seasons at both rates of linuron, metribuzin and oryzalin. *Amaranthus retroflexus* control by these 3 herbicides was excellent only in first season. Yields did not differ between tillage systems. Reduced weed control with metolachlor during both seasons, and possible crop injury with linuron in first season resulted in significant yield reductions.

Pfleeger and Olszyk (2008) found significant yield losses caused by low rates of sulfo-meturon methyl and imazapyr and, to a lesser extent, with glyphosate and cloransulam-methyl. Bromoxynil and MCPA had little effect on the plants.

METHODS

Between years 2011 and 2013 field trials were established with various herbicide applications using recommended and reduced rates. The research was done in 3 replications using de-stoning technology and early ware potato variety Dali was involved.

The aim was to determine, whether low input system could be applied in potato growing with de-stoning technology and whether recommended herbicide rate could be 50 % reduced maintaining required level of weed control effect and the equal yield level. Herbicides were applied on trial plots sized of 50,2 m² using back sprayer Vermorel 2000 electric, the distance nozzle-object was 40-50 cm.

Trial variants:

- Control variant without herbicide application
- Fluorochloridon (Racer 25 EC 2,0 l/ha), manufacturer Makhteshim Agan
- Fluorochloridon (Racer 25 EC 1,0 l/ha) - reduced rate
- Linuron (Afalon 45 SC 1,0 l/ha) + Clomazone (Command 36 CS 0,2 l/ha), manufactuter Makhteshim Agan
- Linuron (Afalon 45 SC 0,5 l/ha) + Clomazone (Command 36 CS 0,1 l/ha) – reduced rate
- Metribuzin (Sencor 70 WG 0,5 kg/ha) + Clomazone (Command 36 CS 0,2 l/ha), manufacturer Bayer CropScience
- Metribuzin (Sencor 70 WG 0,25 kg/ha) + Clomazone (Command 36 CS 0,1 l/ha) – reduced rate
- Prosulfocarp (Boxer 5,0 kg/ha), manufacturer Syngenta Crop Protection
- Prosulfocarp (Boxer 2,5 kg/ha) – reduced rate
- Metribuzin+Flufenacet (Plateen 41,5 WG 2,5 kg/ha), manufacturer Bayer CropScience
- Metribuzin+Flufenacet (Plateen 41,5 WG 1,25 kg/ha) – reduced rate

Application dates:

- I. date (3 days after planting) – var. 2 a 3
- II. date (before emergence initiation) – var. 4,5,6,7,8, 9,10 and 11

Studied indices:

- % weed control efficiency (evaluation done 70 days after planting)
- Weight of green mass of weeds in g/m³ (evaluation done before harvest)
- Potato yield in t/ha (evaluation done at physiological maturity)

Statistical assessment was done using variance analysis and t-test in STATISTICA CZ programme version 10.0 MR1.

RESULTS AND DISCUSSION

The highest frequency of following weeds was found on the plots: VIOAR, LAMPU, CHEAL and GALAP in 2011, VIOAR, LAMPU, CHEAL and GERPU in 2012 and VIOAR, FAGCO, MATCH and GERPU in 2013 (name based on Bayer Code System).

Weed control efficiency

Weed control efficiency was evaluated in % decrease of weed presence compared to untreated control, namely 70 DAP.

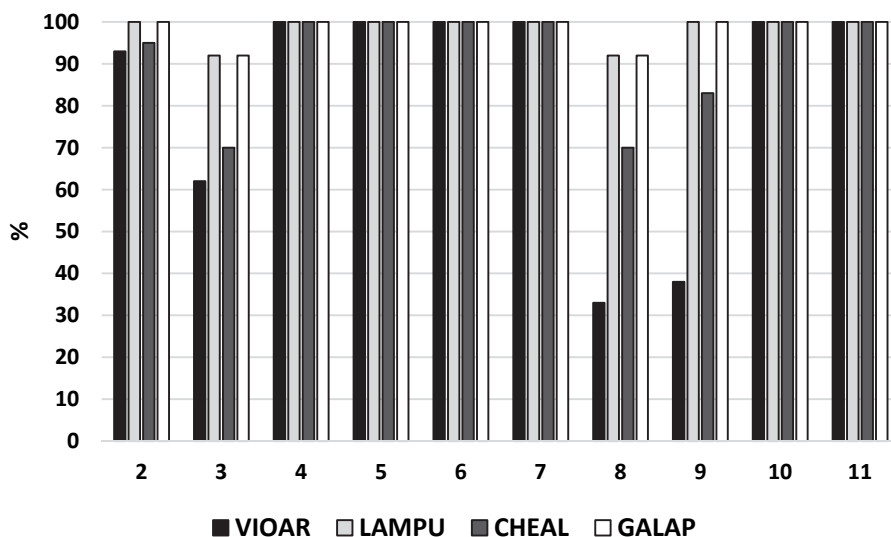


Fig. 1 Weed control efficiency (%) of herbicide application variants in 2011

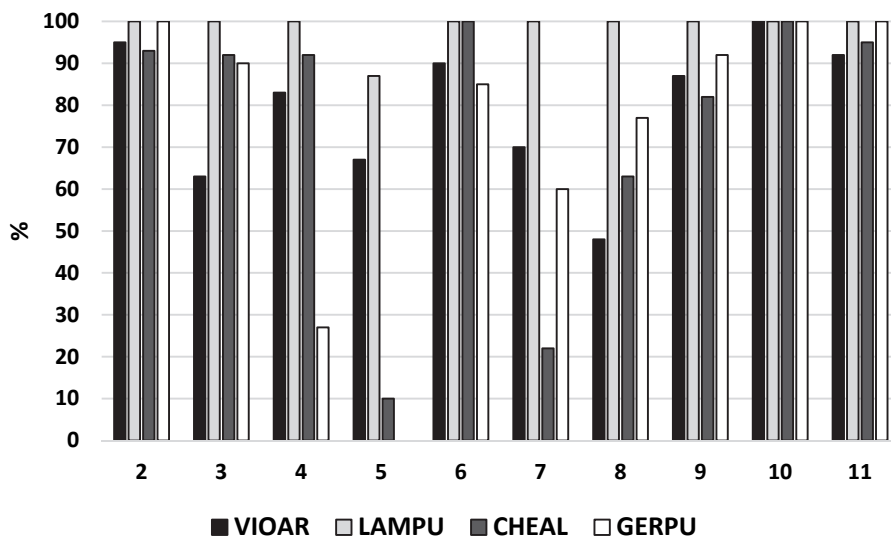


Fig. 2 Weed control efficiency (%) of herbicide application variants in 2012

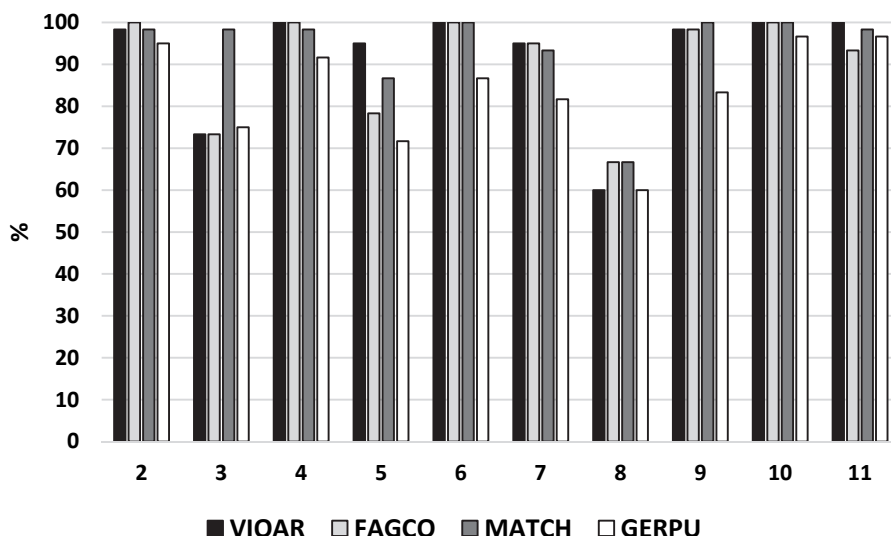


Fig. 3 Weed control efficiency (%) of herbicide application variants in 2013

The figures 1-3 shows weed control efficiency of individual herbicides and a difference between efficiency of full and halved rates (pair of variants 2-3, 4-5, 6-7, 8-9 and 10-11) for four weeds with the highest infestation intensity on the plot in given year.

In 2011, 100% efficiency was recorded for herbicides 4, 6 and 10, lower efficiency was determined in 2 and 8. Reducing rates resulted in efficiency decrease only in herbicide 2.

In 2012, 100 % efficiency was only found in herbicide 10. For other herbicides it ranged mostly between 60 and 90 % based on weed species. Reduction to 50 % rate resulted in efficiency reduction on average of 12 %.

In 2013, the lowest weed control efficiency was found across studied years and except for the variant involving herbicide 8, on average 8 % reduction of efficiency was found with reduction of herbicide rates.

Potato yield

Potato yield (Fig 4) ranged between 54,25 (var. 9) and 66,15 t/ha (var. 10) from herbicide-treated plots in 2011. Potato yield from untreated control was 44,22 t/ha. Except for var. 9 statistical significant increase of potato yield was recorded for all variants compared to untreated control. For variants treated with standard herbicide rates the yield was on average 40 % increased.

Potato yields from variants treated with 50 % herbicide rates were only less than 2 % reduced in mean of these variants compared to variants with standard rates. It is illustrated in Table 1, which evaluates potato yield across variants with full and 50 % herbicide rate. The results obtained in 2011 show that reduced herbicide rates did not influence potato yields on statistically significant level.

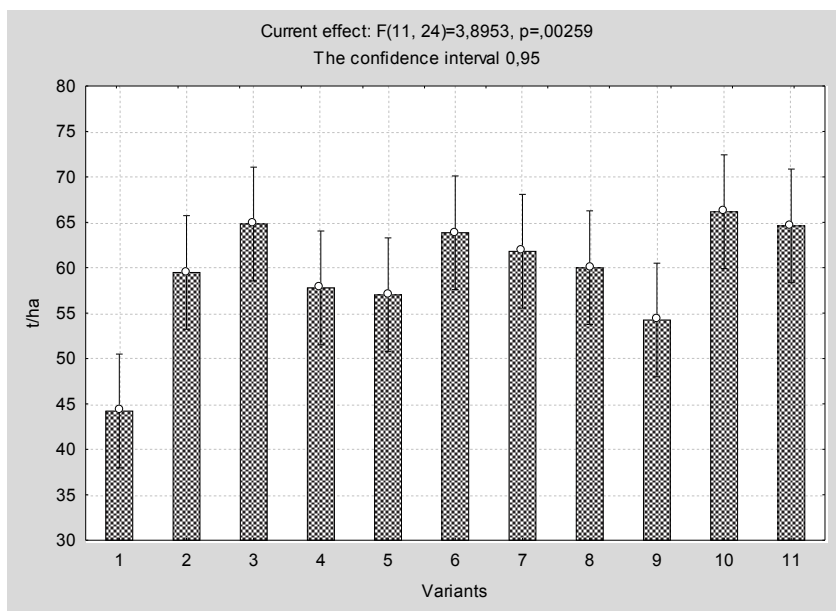


Fig. 4 An effect of variants on potato yield (t/ha) in 2011

Table 1 Statistical assessment of variants with full and 50 % herbicide rates in years 2011 – 2013 (means followed by the same letter within a column do not differ significantly (Tukey's HSD, $P=0,05$).

year	full dose	reduced dose
	average yield (t/ha)	average yield (t/ha)
2011	61,43a	60,46a
2012	43,98a	42,33a
2013	47,45a	49,29a

Potato yield in 2012 (Fig 5) ranged between 38,84 t/ha and 46,53 t/ha on plots treated with herbicides. Potato yield from untreated control was 32,28 t/ha. On variants with standard herbicide rates on average 27 % potato yield increase was determined compared to untreated variant.

Potato yield in variants treated with reduced herbicide rate was on average of these variants only by 2 % reduced compared to variants with standard rates similarly as in 2011 (Tab.1). The results obtained in 2012 show that reduced herbicide rates did not influence potato yield on statistically significant level.

Potato yield in 2013 (Fig 6) ranged between 34,43 and 56,32 t/ha in herbicide-treated variants. Potato yield from untreated control was 21,84 t/ha.

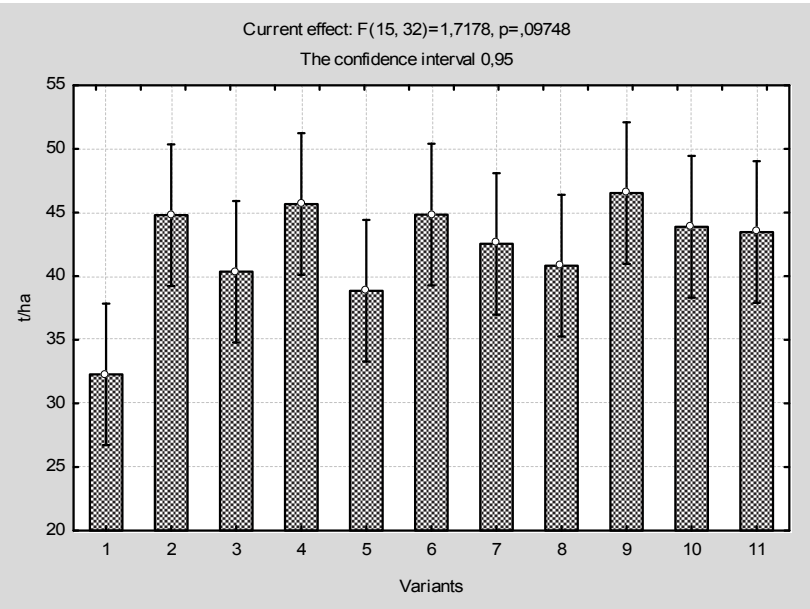


Fig. 5 An effect of variants on potato yield (t/ha) in 2012

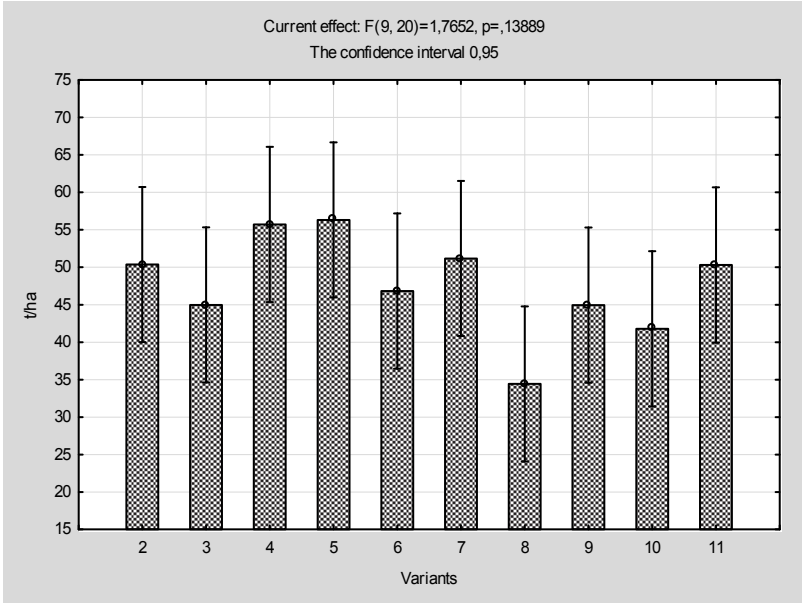


Fig. 6 An effect of variants on potato yield (t/ha) in 2013

Mentioned values indicate that herbicide application increased (on average of all variants – herbicides and also rates) potato yield by 110 % compared to untreated control variant. This high yielding effect of crop herbicide treatment was caused by high occurrence of weeds on trial plot. In variants treated with standard herbicide rates insignificant 8 % reduction of yield was determined. The results from 2013 confirm previous finding that reduced herbicide rates did not influence potato yields (Tab. 1).

The results from similar trials of other authors show the possibility of reducing herbicide rates combined with other measures, such as mechanical cultivation (Melander et al. 2003, Bellinder et al. 1996).

When rates were reduced without subsequent measures, results were unambiguously not in favour of reduced rates every year (Easson et al. 1996) or reduced rates were not effective (Wallace et al. 1990).

CONCLUSIONS

The trials show that 50 % reduction of herbicide rate did not have an effect on potato yield (no statistical significant differences were found between variants). Weed control efficiency, measured toward the end of vegetation, was not reduced in the first trial year due to variants with herbicide reduction; in following two trial years efficiency was 8-12 % reduced. However, this reduction was not expressed in potato yields. The reason is that efficiency reduction did not reach threshold of harmfulness of weed species. Significant differences in potato yields were not found between variants, except for the variant without treatment.

From research standpoint reduced herbicide application could be recommended.

ACKNOWLEDGEMENTS

The results of the study were obtained within the research plan MSM6010980701 and QI 101A184

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LINKING VERNACULAR ARCHITECTURE AND ENVIRONMENT: THE CASE STUDY OF THE MARCHE REGION (CENTRAL ITALY)

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SUMMARY

The Marche region, in Center Italy, shows a rich heritage of traditional earthen constructions. The bulk of this patrimony had been formed between the XVIth and XXth centuries, when the sharecropping system was ruling the most part of rural lands. In Italy, earthen buildings have known rising and declining fortune, up to the second half of last century. The main argument against such an ancient method of construction was that it is utterly unsuitable when earthquake hazards are high. Furthermore, detractors claim on a commonplace which considers earthen buildings as unhealthy and beggarliness. Despite the rising evidences, brought along by ecological movements in architecture since the seventies, that raw earthen shelters elicit a healthy microclimate, the normative standstill in the Italian context has led to the abandonment of these vernacular construction techniques. In recent times, improvements in the shared sight of the European Commission aiming to mitigate soil sealing and to achieve no net land take by 2050, and the booming of bio-architecture, have risen the possibility to give new roles to the raw-earth. Amongst the different methods of vernacular architecture, raw-earth was a promising one under cultural, ecological, and economic points of view. Many authors studied the manifold aspects outlined by this method: history of predominant buildings, methods of inventory, social uses, building techniques and, recently, restoration of pre-existence constructions. In contrast, little attention has been paid to the relationship between artefacts and the surrounding environment, particularly the relationship between the characteristics of the soil in the close perimeter of the building, and the raw materials that compose the artefact. The bulk of this research aims to fill this gap and to strengthen the knowledge on the regional heritage of earthen buildings, considering both the different construction techniques and the

specific environmental conditions where the buildings were settled. To this end, more than two hundred predominant buildings have been geo-located spread over the whole region. Subsequently, the database has been embedded with information on the lithological substrates upon which the houses were located. A set of samples of soils and building materials has been collected and characterised by lab analyses. The outcomes allowed us to characterize the materials composing the sampled earthen houses and to classify the artefacts into homogeneous groups. On a greater extent, shedding light on the relationship between artefacts and their environment, our research aims to contribute to improve the sense of place within the local community.

Key words: *Earthen Construction, GIS Inventory, Soil, Environment*

INTRODUCTION

The use of raw-earth as a building material has ancient origins. The earliest examples of raw-earth constructions are dating around 2000 BCE in Asia (eastern China), while the earliest European examples are Phoenician structures dating back between 1200 and 539 BCE (Jaquin, 2008). Nowadays it is estimated that from a third to a half of World's population - approximately three billion people - lives in buildings made of earth (Keefe, 2005; Rael, 2009). Starting from the early XX century, in the most developed European countries, with the advent of modern construction materials like fired bricks and concrete, all traditional vernacular building techniques, in particular those based on raw-earth, were progressively abandoned (Beckett, 2011). This process has led to a significant loss of cultural identity and traditional skills in rural areas of many countries where raw-earth constructions have been spread for centuries. As a result, existing structures were exposed to degradation and the perception of earthen structures as sub-standard buildings has grown up among common people (Palombarini, 2002; Delgado, 2006). For those reasons, in most European countries, the earthen buildings were relegated within a cultural and technical niche of the past decades.

Recently, however, the cultural rediscovery of this very significant heritage (ICCROM, 1993; Houben, 1994; Conti, 2009; Chabenet et Al. 2011; Niroumand, 2013; Correia et Al., 2014) and the eco-sustainability offered by these materials have led to a renaissance of the earthen construction techniques. Little energy is needed during the construction (Treloar et Al., 2001), and almost all materials used for earthen buildings are completely recyclable; thus, the environmental impact and the soil sealing are largely reduced (Delgado, 2006). Raw-earth constructions perform well thermally (Martín et Al., 2010), allowing the buildings good thermal insulation capacities and thermo-hygrometric comfort of the indoor environments, including sound insulation (Binici et Al., 2009).

Despite these rising evidences, brought along by ecological movements in architecture since the seventies, the actual normative constraints in the Italian context have strongly reduced the spread of earthen construction techniques. In recent times, improvements in the shared sight of the European Commission aiming to mitigate soil sealing and to achieve no net land take by 2050, and the booming of bio-architecture have risen the possibility to give new roles to the raw-earth. Probably, the definition of new perspectives for the re-proposition of raw-earth as self-building solution, aiming to solve the building needs linked

to farming activities in rural areas, has to face two main questions: the lack of skilled people (designers and masons) in this specific area (Quagliarini et Al., 2010), and the insufficient knowledge of the more suitable environment where to place the earthen buildings. As a matter of fact, little attention has been paid on the relationship between artefacts and their surrounding environment, in particular between the characteristics of the soil substrates in the vicinity of the building, and the raw materials composing the artefact (Makinde, 2012). Conversely, historical studies and inventories on earth architecture are not negligible in Italy, confirming that in every region there are examples of earthen buildings (Jacini, 1883; ISTAT, 1936; Baldacci, 1958; Palombarini, 2002).

The bulk of this research aims to fill this gap, strengthening the knowledge on the regional heritage of earthen buildings in Marche region (Italy) and considering both the different construction techniques and the specific environmental conditions on which the buildings were settled. For the purposes of this research, the most recent inventory compiled for the medium hilly area of the Marche Region was taken into account (MIBAC, 2005). This allowed us to consider more than two hundred raw-earth buildings. This patrimony was built over centuries, and the buildings assumed different local words that characterize the typical earth houses of the Marche region: *atterrato*, *pagliara*, *cassette*, *case a piancato*, etc. In the Region, even different building systems have been identified. The technique internationally known as *cob* or *bauge*, which is present in Italy with local variations, has been significantly spread in the Marche region where it is called *maltone* or *massone*. Other earthen building systems recognized in the Region are the *pisè* (or *rammed earth*) and *adobe*, but they were used rarely. In certain cases, a mix of these different techniques were applied. In the first step of the research, all earth buildings listed in the MIBAC (2005) inventory have been geo-referenced through a GIS platform, in order to intersect the information on lithological substrates upon which the houses were located. After this, a specific field campaign was implemented to collect and characterize samples taken from the buildings' walls and the surrounding soils. The outcomes have allowed us to characterize the materials composing the sampled earthen houses and the respective soils, and to classify the artefacts into homogeneous groups.

MATERIALS AND METHODS

Starting from the data reported in MIBAC (2005), a distribution map of the earthen houses across the Marche region has been obtained in GIS environment at a scale 1:100,000. Most of the predominant buildings inventoried by MIBAC (2005) (i.e., 242 elements) has been subdivided on the basis of the lithological substrates on which they are placed. As the great part of these houses fall in the hilly peri-Adriatic area, the lithologies are represented by fine to coarse grained sediments spanning from Messinian to Holocene. On the inner, mountainous area dominated by limestone, no earthen house was found. For each building, a specification list was compiled by considering: building type and technique, current use, location; moreover a comprehensive photographic survey was accomplished. Building position was also overlayed with the main characteristics of the surroundings (geology, geomorphology and hydrogeology). This was possible after to have produced a simplified geology map at the scale 1:100,000, which took into consideration lithological similarities in terms of particle-size distribution, regardless their chronology (Fig. 1).

Class of lithologies	Class description
1	Present-day and recent alluvial deposits, river delta and beech deposits; Holocene
2	Foothill, detritic, and alluvial/colluvial deposits; Holocene-Late to Middle Pleistocene
4	Alluvial terraces; Late Pleistocene
5	Alluvial terraces; Middle Pleistocene
7	Conglomerates and sands interbedded with siltstones and gastropods; Lower-Middle Pleistocene
8	Thinly layered pelitic-sandstones and siltstones; Lower Pleistocene-Middle Pliocene
9	Thin-to-thick layers of arenaceous pelites; Lower Pleistocene-Middle Pliocene
11	Pelites interbedded with thinly layered pelitic- sandstones; Lower Pleistocene
12	Conglomerates, sands, sandstone interbedded with shales; Lower Pleistocene- Middle Pliocene
13	Pelitic deposits; Lower Pleistocene-Middle Pliocene
23	Pelitic deposits interbedded with undifferentiated coarser deposits; Lower Pliocene
27	Pelites; Lower Pliocene
32	Marly shales and clay marls interbedded with sandstones and evaporates like micritic limestones (known as <i>argille a colombacci</i>); Late Miocene (Messinian)
38	Pelitic arenaceous deposits interbedded with rather thick coarser deposits (known as <i>formazione della Laga</i>); Late Miocene (Messinian)

Fig. 1 Legend of the simplified geology map

From five selected houses, samples were collected from walls with N to NW aspect. At each site, soil samples were collected from the surroundings. For this purpose, we opened a pit of about 45 cm of depth, described soil morphology, and collected the brown soil belonging to the B horizons. Each wall and soil was collected in triplicate. All the samples were sieved at 2 mm to separate the coarse fragments (> 2 mm) from the so called fine earth (< 2 mm). This latter fraction was submitted to the following analyses. Particle-size distribution was determined after the dissolution of organic cements by NaClO at pH 9 (Lavkulich and Wiens, 1970). Sand was recovered by wet sieving, while silt was separated from clay by sedimentation maintaining the columns at 19-20°C. The pH was determined potentiometrically in water with a solid:liquid ratio of 1:2.5. The organic C content was estimated by the Walkley-Black method without the application of heat (McLeod, 1975).

Soil mineralogy was determined by x-ray diffraction methods. Crystalline minerals were identified by analyzing manually oriented powdered specimens on a Philips PW 1830 (Philips, Eindhoven, Holland) x-ray diffractometer, using Fe-filtered Co K α 1 radiation (35 kV and 25 mA); the step size was 0.02° 2 θ and the scanning speed was 1 second per step. Semi-quantitative estimation was obtained by identifying the minerals on the basis of their characteristic peaks. The mineral content was assessed from the area of the respective primary peaks, calculated by multiplying the peak height by the width at the half-height.

RESULTS

Earthen buildings are present in the four provinces of the Region, even if they are more diffused in the Macerata and Ascoli Piceno provinces (Fig. 2). Moreover, also the distribution pattern with respect to lithology differed as it was rather uniform in the Northern provinces (Ancona and Pesaro-Urbino) and remarkably differentiated in the Southern ones (Macerata and Ascoli Piceno). In particular, at South, the Class 2 alone included as many as 33.5% of the known buildings. Furthermore, a set of classes (8, 9, 11, 13, 23, 27, 38) representing "thin to thick layers of pelitic-sandstones and siltstones, and pelitic sediments" clustered 41% of artefacts. Few buildings (1.7%) felt in the Class 32, made of very clayey lithologies.

Considering the construction technique, there is a clear prevalence (76% of the total) of that known as *malton-massone*, which consists of a superimposing lumps of earth and straw of roughly cylindrical shape, weighing 5-10 kg, when they are still in the wet state so as to favour adhesion one to each other. They undergo a certain compression during the construction of load-bearing masonry, who proceeds in a discontinuous way layer to layer with a height of 50-70 cm. It could be assumed, therefore, that the lithologies over which buildings presence is high, had the characteristics that made them particularly suitable for the construction of the earthen buildings by means of this technique. For this reason, we have proceeded to deepen the investigation by sampling and analysing the terrigenous material taken from some of the buildings and from the adjacent area.

Generally, in both houses and surrounding soils, particle-size distribution showed a prevalence of the silt and sand fractions, with a very scarce clay content (Table 1).

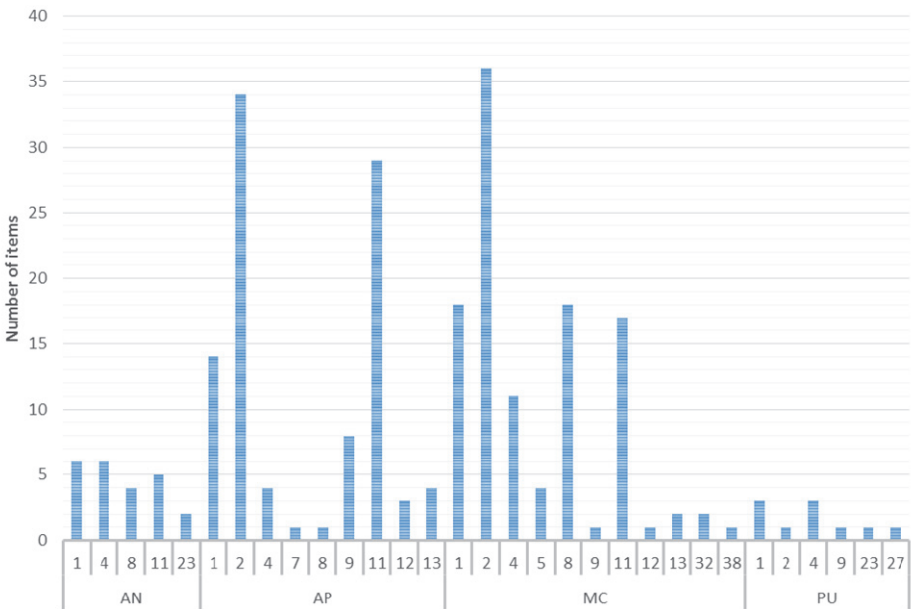


Fig. 2 Distribution of earthen houses per lithological class and province

Particles larger than 2 mm (skeleton) are almost absent. Only in the house 1 sand largely prevailed but this was not true in the soil 1. In all the other cases, sand and silt contents were rather similar between soil and corresponding house. This indicated that, in general, the material used to build houses was the soil in the vicinity of the construction, and this happened possibly after to have selected the site where the soil material was suitable for that aim. Nonetheless, the mason's skill must be so high to understand when it was necessary to make additions to improve the performance of the material. This was probably the case of house 1: if it has been made with the soil 1, this latter was evidently added of sand material. However, judging from the pH values, except for soil 5 all the others appeared to have been added of some that was able to reduce pH. However, as pHs higher than 8.25 indicated the presence of Na_2CO_3 , which is more soluble than CaCO_3 , it is possible that the simple addition of water to knead the soil was able to eliminate Na_2CO_3 , so contributing to reduce the pH to values around 8 or less. The values of humic carbon, always higher in the soils than in the houses, would suggest that the earth was modified by addition of materials with low C content or elimination of the more soluble organic compounds due to leaching.

Tab. 1 Particle-size distribution after NaClO treatment, pH and humic C content for earthen houses and their surrounding soils; Marche Region, Italy; The values in parentheses are the standard errors ($n = 3$)

	Sand	Silt g kg^{-1}	Clay	pH	Humic C g kg^{-1}
House 1	758(23)	233(22)	9(1)	7.80 (0.02)	9.96 (0.19)
House 2	330(34)	631(40)	39(6)	7.84 (0.01)	10.78 (0.05)
House 3	380(34)	608(36)	12(2)	7.52 (0.00)	5.03 (0.10)
House 4	504(42)	481(43)	15(1)	7.88 ((0.00)	5.48 (0.24)
House 5	530(45)	456(46)	14(1)	8.13 (0.03)	4.83 (0.19)
Soil 1	369(27)	580(32)	51(5)	8.51 (0.00)	13.36 (0.14)
Soil 2	425(29)	538(36)	37(7)	8.41 (0.04)	11.77 (0.29)
Soil 3	306(32)	670(28)	24(4)	8.44 (0.04)	11.87 (0.19)
Soil 4	469(20)	501(25)	30(5)	8.52 (0.04)	7.25 (0.19)
Soil 5	553(23)	417(27)	30(4)	8.21 (0.07)	7.64 (0.00)

The X-ray diffraction analyses of house and soil samples (Fig. 3) indicated that the most represented minerals were calcite, dolomite, plagioclases, quartz, micas, kaolinite and small amounts of expandable minerals (2:1 clay minerals). In 4 over 5 cases, houses and corresponding soils were very similar, except for a higher amount of calcite in the houses; this was probably the result of lime additions during the mixing of the soil material. In contrast, house 1 substantially differed from soil 1 for the presence of considerable amount of olivines, which are volcanic minerals. In addition, diffractograms of house 1 also showed

a large shoulder between 15 and 20 °2θ that was absent in the trace of soil 1 and that is usually attributed to amorphous minerals such as glass or short-range order minerals. The presence of olivines and amorphous minerals indicated the presence of volcanic materials. In a Region where volcanoes and volcanic sediments are absent, the presence of these minerals into the house walls can be ascribed to the addition of pozzolanic ash to the soil material. This would also explain the higher sand content of this house with respect to its surrounding soil. The diffractometric results further suggested that soil materials were probably selected also for their small content of 2:1 clay minerals. In fact, the expandability of these minerals could produce detrimental effects on the wall resistance and, even though the walls were daubed to avoid the soil material came in contact with the water, the scarcity of expandable minerals represented a further guarantee of a proper performance.

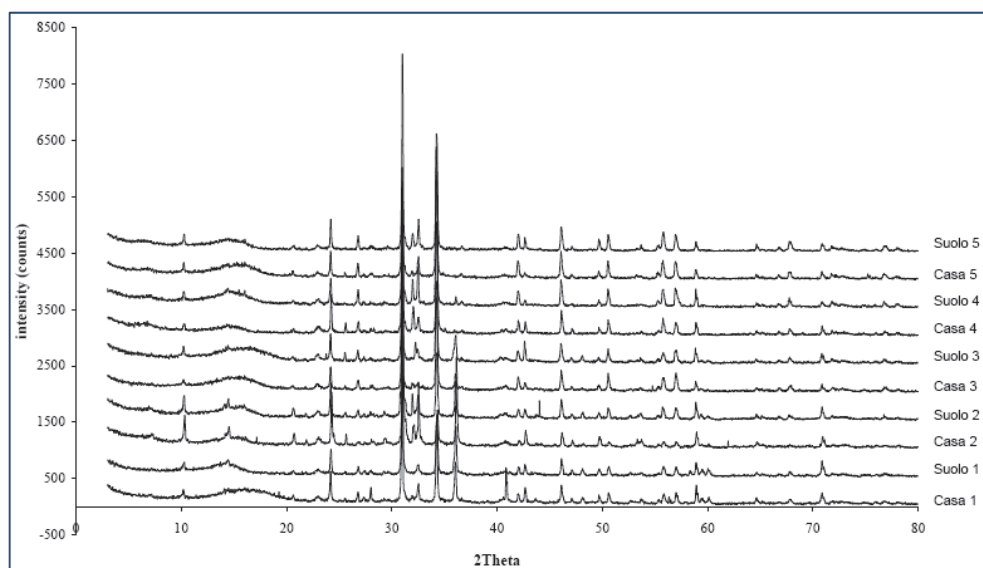


Fig. 3 X-ray diffractograms of houses and surrounding soils; Casa=house, Suolo=soil

CONCLUSIONS

In this work authors report that most of the earthen houses of the Marche Region (Italy) has been constructed by the technique internationally known as Cobe or Bauge, and that these houses are mainly diffused in the hilly peri-Adriatic area where the lithologies are represented by fine to coarse grained sediments with scarce or absent skeleton dating back from Messinian to Holocene. Soils developed from these lithologies have inherited much of the initial character of the parent materials, and represented a suitable material to be used for constructions.

Usually, the particle-size distribution is similar in both houses and surrounding soils, even though we have assessed that, with the aim to improve the performances of the constructing dough, masons had probably modified the soil by adding different materials

such as straw or volcanic matter, and knead the mixture by adding water so to obtain a material judged adequate for the necessity.

This work represents a first contribution in the way to explore relationships between natural resources of a territory and the diffusion of earthen houses. This sort of studies also aim to recall the construction techniques of the past and, for this, further studies are needed in other environments, and to deepen the knowledge on the analytical point of view.

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THE VALORIZATION OF VERNACULAR FARM BUILDINGS FOR AN INNOVATIVE RURAL TOURISM

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SUMMARY

The recent growing research of new ways for widening sustainable tourism opportunities leaded, in many European countries, to the valorisation of some farmyards, together with the working activities usually conducted there. Rural tourism offers new ways for enjoying the agricultural land in close contact with naturally untouched landscapes, often coupled with the unique opportunity to personally look at the preparation of traditional genuine food products, with the possibility to taste and buy them. In this way, rural tourism enables to appreciate some traditional aspects that the new industrialized modern society may have forgotten.

For a sound valorization of rural tourism, a suitable restoration and functional requalification of the farm building plays a central role. With the aim to plan a common approach about new innovative ways for valorising rural tourism, mainly in mountain areas, in the present paper a first analysis focused on the possibilities of exploiting agricultural activities and restoring vernacular farm buildings for rural tourism was conducted, with reference to some areas located into different countries of the Adriatic-Ionian Macro-region. Some vernacular farm buildings, synthesizing in their architectural expression the culture, traditions and ways of life of different generations of rural population, were identified and analyzed in their typology, with the aim to detect and compare their architectural aspects.

The results of this survey enable the drafting of an innovative common protocol for planning suitable technical and economical interventions aimed to the revitalization of mountain rural areas, through the organization of a network

focused on the valorization of common agricultural activities and production of local traditional foods, together with the exploitation of rural tourism activities, geared by the restoration of vernacular farm buildings according with specific common specs, able to recover them in such a way to balance at the same time their traditional vocation and the environmental sustainability of the landscape they are incorporated into.

Key words: Rural tourism, mountain areas, vernacular farm buildings, rural landscape, Adriatic-Ionian Macro-region

INTRODUCTION

Tourism is one of the most important economic sectors in which the future development of marginal areas, as those included within wide mountainous regions, could be based. Due to their location, far from the most important transportation routes and from big industrial and commercial centres, these areas may mostly benefit from the improvement of their touristic offer, based on local traditions, environmental uniqueness, and landscape beauty. These areas, widely diffused in the Mediterranean basin, are mainly concentrated into Balkan countries as well as within the internal areas of other Countries, like the Italian regions crossed by the Apennine mountains.

One of the most important factor able to play a key role for boosting the tourist offer in these areas is the traditional architecture. Vernacular farm building is one of the most intriguing example of original technical and scientific issues along the past centuries: designed to accommodate its internal biological production, it has no other comparable example in the wide epistemological sector of building construction. The birth, growth and development of living vegetal or animal organisms, contained inside these volumes, raise architectural and engineering plant issues with no similar comparison in other technological sectors. Aimed at producing optimal environmental conditions for plants and animals - at the same time, protecting hygiene and health of workers involved in the daily operations of care of living organisms at different stages of their development - the rural building constitutes an unique and unmatched technological model. The originality of what is happening *inside* the farm buildings then also corresponds to what happens *outside* of them [Picuno 2012]. The role that the buildings have historically played is strictly connected with the surrounding environment, due to the need of the farmer to live in close contact with agriculture and animal husbandry. If the organization of human beings involved in the activities of the industrial or tertiary sector allowed aggregation in urban centres, conversely the need to live in constant contact with the agricultural production developed a synergetic function of close proximity to the rural land. This has led to the spread in the rural area of many examples of buildings that served as buildings for farming, storage and processing of agricultural products constituting, at the same time, housing for the farmer and his family.

Vernacular farm building and rural landscape

A vernacular farm building is a living witness of how humans have populated, in harmony with the natural elements, the agricultural land, joining the agricultural production needed for human nutrition with the control and care of extra-urban land [Dal Sasso &

Caliandro, 2010; Van der Vaart, 2005]. Therefore, the interventions made by the Man often strongly influenced the agricultural environment and the visual perception of its landscape [Hernández et al., 2004; Picuno et al., 2011; Statuto et al., 2013; Tortora et al., 2015]. As in many cases all over Europe, and more specifically in the Mediterranean area, these factors led to the realization all over the Centuries of many buildings that, designed in order to satisfy their main agricultural role, now constitute a widespread heritage of unrivaled architectural value, that should be taken in the highest consideration during the process of landscape planning [Fuentes et al., 2010; Statuto et al., 2014].

In many cases, vernacular farm buildings are also excellent examples of use of the concept of bio-climatic design. Bioclimatism, displaying years of embodied experience built on the relationship between building and climate, satisfies the needs of human beings (thermal, luminous and acoustics) by focusing on a holistic approach that considers the role of the external environment [Vissilia, 2009]. As observed by Coch [1998], modern buildings, clad in glass as a symbol of their modernity, are incongruously dark and require artificial lighting during the day, while the flimsy casing separating them from the outside makes it necessary to use air conditioning all year round, even when outside conditions are pleasant. These buildings are so wrong that they work worse than the climate. Bioclimatism is currently analyzed by many Scientists all over the World [Labaki & Kowaltowski, 1998; Ratti et al., 2003; Cañas & Martin, 2004] as the way that was employed in the past for assuring sound climatic conditions to inhabitants through simple building processes based on the exploitation of natural factors as external climatic conditions, site topography, *etc.* In some cases [Singh et al., 2009] bioclimatic architecture was also proposed as a new model for recovery vernacular construction.

MATERIALS AND METHODS

In order to verify the typological characteristic, building condition and status of use of rural buildings, an analysis was conducted in order to identify the most popular features of these buildings located within some areas of the Adriatic-Ionian Macro-Region. The EU Strategy for the Adriatic and Ionian Region (EUSAIR) is a macro-regional strategy adopted by the European Commission and endorsed by the European Council in 2014. One of the four main pillars on which this Strategy will be concentrated is sustainable tourism.

The core methodological procedure used in this study is geographically spatial method, combined with some direct investigations that, identified as a field method, included the direct exploration followed by observing. The study of geographical method was related to rural settlements located into the mountainous areas within three regions of the Adriatic-Ionian Macro-region: Basilicata – a small region located into Southern Italy whose territory is 90% mountain – Montenegro and Serbia.

Basilicata covers a total surface of almost 10,000 km² and a population of about 610,000 units, distributed into the two Provinces of Matera and Potenza (figure 1).

Montenegro is situated in South-east Europe, on the Adriatic sea, and covers a total surface of almost 14,000 km². With its population of about 660,000 inhabitants, Montenegro represents one of the smallest European countries. More than 90% of territory is rural in character and great diversity of natural and built resources and attractions in rural areas,

offer wide possibilities for its sustainable valorisation, especially through rural (eco)tourism and other complementary activities. In geographical sense, it is possible to identify three main regions: South (Coastal), Central and Northern region. Each of them offer specific forms of “typical” Montenegrin rural farm buildings, adapted to geomorphology, climate, traditional way of living and production (e.g. “paštrovska kuća”, “bokeška kuća”, “durmitorska kuća”, “savardak”, “katun” etc.).



Figure 1 Basilicata Region within the Adriatic-Ionian Macro-Region

Located at the crossroads between Central and Southern Europe, Serbia is found in the Balkan peninsula and the Pannonia Plain. The country covers a total of 88,361 km² and has 7,186,862 inhabitants. 70% of the total area is considered to be agricultural land while 30% is under woods. Arable land covers 48,670 km².

RESULTS AND DISCUSSION

Basilicata

According with the most recent available statistical data – ISTAT [ISTAT 1991] - in the Basilicata Region there are more than 11,000 farm buildings, whose breakdown by age of construction is shown in Table 1. More than a mean than one farm building per km² is therefore present all over the Regional land.

The number of houses dating before the early of the 20th century is not so high, reflecting the fact that at that time the owners were few due to the form of land ownership (latifundium, *i.e.* large estate), workers probably coming from small towns nearby. Franciosa [1942] classified the farms widely distributed throughout the region mainly basing on their altitude, their constructive characteristics being very sensitive with the meteorological conditions. This had a significant influence also on the bioclimatic properties

of the building, that was conceived and built on the basis of exploiting natural factors (*i.e.* sun, wind, *etc.*).

Table 1 Rural buildings in the two Provinces (Matera and Potenza) of the Basilicata Region classified basing on their building age

Province	Building age							TOTAL
	Before Year 1919	From 1919 to 1945	From 1946 to 1960	From 1961 to 1971	From 1972 to 1981	From 1982 to 1986	After Year 1986	
Matera	343	413	1990	576	482	111	114	4029
Potenza	1014	957	2264	999	812	648	732	7426
Total Region	1357	1370	4254	1575	1294	759	846	11455

Basing on the results of the typological analysis that was carried out in the present work, it is possible to conclude that the main part of the vernacular farm buildings that were detected are located into mountain areas. These last could be catalogued according with the categories reported in Table 2.

Table 2 Classification of rural buildings of the Basilicata Region [Picuno, 2012]

N.	Typology	Sub-typology	Location in the Regional land
A.1	Temporary housing	Rural huts	Potenza Province
A.2	Temporary housing	Caves	Potenza Province
A.3	Temporary housing	Separate shelters for daily or seasonal stay	Potenza Province
A.4	Temporary housing	Simple building for daily or seasonal stay	Metapontino plain
B.1	Specific forms of government	Colonial type	Vulture-melfese area Lavello/Rionero
B.2	Specific forms of government	Casini holiday Little fortress	Vulture-melfese area Maratea
B.3	Specific forms of government	Farms of composite structure	Matera Province Metapontino plain

The lodgings of elementary type, whether in hill or mountain, currently appear abandoned or used as shelters for the exercise of seasonal breeding. Among the temporary housing in mountain environment, most rural huts and caves are located in the Province of Potenza at altitudes higher than 1,000 m. They usually show (figure 2) a structural and functional degradation that, in some cases, is unfortunately quite advanced.



Figure 2 Rural hut located in the Province of Potenza

Separate shelters for the home daily or seasonal basis can also be found along the mountain or hilly areas near the valleys of the rivers crossing the Region. Lodgings of elementary type, but characterized by a better architectural merit and a greater emphasis on stylistic forms are found in the north-eastern are of Basilicata Region, where an external stair is frequently present. This is the case of the farm "Masseria Giannini" (figure 3) located in Monticchio Lakes in the territory of Rionero, in the "Vulture-melfese" Park Area.



Figure 3 Masseria "Giannini" at Monticchio Lakes (Rionero)

As a conclusion, the analysis performed in Basilicata Region has confirmed the main role played by altimetry in characterizing different architectural types: mountain and high-hill areas are in fact recurring types of lodging characterized by a simple construction, often on one floor. Conversely, in areas at lower altitudes, rural housing, also known with the traditional name of "*Masseria*", was expanding in size, in many cases including, in addition to the main house of the owner, also residences of the settlers and the structures used to the livestock production activity or processing of the agricultural products. Unfortunately, the most part of the vernacular farm buildings that were detected and analysed, whether on hill or mountain, resulted currently abandoned or seldom used as shelters for the exercise of seasonal breeding [Manera et al., 1990].

Montenegro

According with Rajović and Bulatović [2013] the process of depopulation in rural settlements of northeastern Montenegro, in the seventies of the twentieth century, has reached worrying proportions. These Authors, focusing a specific analysis in northeast Montenegro, analyzed the chronology of the types of housing facilities and ancillary farm buildings in rural settlements in that area, that differ according with the following morphological types of permanent residence:

1. Primitive forms of human habitats (dugouts - cave dwellings, semi-dugouts)
2. More advanced forms of habitat (cottages) and
3. Contemporary housing facilities.

The total number of dwellings that were detected in that study area was n. 12.240 housing, going from log cabins with one separate room to chalet with five-room and more apartments. The most part of these dwellings is currently equipped with water supply (n. 9.242 over the total of 12.240), electrical power (n. 12.171, almost the totality) and auxiliary premises, *i.e.* bathroom (n. 7.555, that is more than the 60%).

The lack of certain infrastructure, especially high-quality roads, to a great extent reduces the quality of the housing stock in rural settlements of the region, which along with its other characteristics make the typical image of good part rural settlements in Montenegro. Anyway, since the specificity of rural settlements outstands quality of the environment, from that point of view it is observed a remarkable synthesis of complementary economic activities (agriculture and tourism), as well as their ecological character (figures 4, 5).



Figure 4 Traditional stone dwelling with straw roof in Čevo (Montenegro)

The tendency to revive the good old and functional forms of housing in rural areas today is, fortunately, more and more present. More and more people are who want the existing old house renovation, as well as the tradition, through new architectural forms inspired to the traditional rural architecture. However, to order to avoid merely replication of form, it is

very important to choose correct solutions, employing the natural materials that were so carefully chosen by the old builders and which was the basis for the construction of a pleasant and functional residential house [Lista et al., 2013].



Figure 5 Vernacular farm building (Kuća) in landscape in Kolašin (Montenegro)

In this sense, tourism could be considered as a means of counteracting of the social and economic challenges facing rural areas in Montenegro, primarily those associated with the decline of traditional agrarian industries [Moric, 2012]. A special role of rural tourism is identified in generating new jobs and additional incomes at farms. Moreover, expanding activities in the development of "rural" tourism or "ecotourism", where the granting accommodation capacities create the conditions guests staying and developing new social and economic quality, would then reduce emigration from of rural settlements, and create conditions for the rural revitalization.

Serbia

Traditional architecture is an important factor in tourist offer in rural mountain areas of Serbia. Tourism is one of the most important economic sectors in which (together with industry and agriculture) the future development of Serbia is based. This was confirmed in the latest planning document at the national level, the Spatial Plan of Serbia 2010-2014-2021 [Pavlovic et al., 2012].

The traditional architecture of rural mountain areas are: traditional houses and economic buildings, wooden churches and windmills, which were abandoned and ruined. Log cabin house is typical for the mountain areas of the Balkan Peninsula. Logs were placed at the four stone corners and folded on the other logs. The floor was earthen, fireplace was located in the middle. Log cabin did not have an attic. The roof was made of straw, or later shingles. Shingles represent a roof of wooden planks, which are placed one over another. Roofs were high and steep, so that the snow melted faster. Chimneys are tall and massive to perform better ventilation. Log house has a basement, a room above it. The cellars are deep to maintain constant temperature and keep food from spoiling.

Numerous examples of rural mountain houses in Serbia have disappeared over the last two decades. Therefore, some actions such as recording of these facilities, protection of space in which these were built, renovation of buildings that are authentic, respecting the legal framework of house owners, should be taken, with the obligation of maintenance, management and operation of tourism (Fig. 6).



Figure 6 A 2-storeys version of a “Moravian” house (Serbia)



Fig. 7 The traditional building museum in Sirogojno - Mount Zlatibor (Serbia).

Thanks to tourism, buildings in which traditional activities do not take place, get different purpose. They retain the old form and receive new content. Built objects are used as tourist information, restaurants and cultural spaces (galleries, exhibition rooms, theatre and concert halls). New facilities should be adequate for the old function. Objects of folk architecture are in the function of eco-workshops, courses of traditional cooking, crafts schools. It is necessary to respect the principles of typical and specific areas in which objects of folk architecture are accommodated. In villages that have retained traditional

features, tourists stay in an authentic, functional and aesthetically shaped space. If there is need for adaptation, the house must preserve the traditional architecture. Some of the best examples of well-maintained vernacular farm buildings in Serbia were converted in the rural ambience of the whole, forming museums in the open sky. This is the case of the Museum in the open “Old Village”, in the village of Sirogojno, in south-west Serbia (fig. 7).

CONCLUSIONS

The analysis that was carried out about the lodgings into three different regions located in the Adriatic-Ionian Macro-Region revealed the existence of a number of types of architectural characteristics, in some cases inspired by common building rules. Most of these vernacular farm buildings, realized during the past centuries, are in fact living witnesses of old and wise capacities of our forefathers in designing buildings in a way that fosters the natural components able to maintain optimal climatic conditions inside “living” buildings, where humans, animals, crops, in one word living organisms, could find better conditions than in the open field.

The opportunity to restore some of these buildings, by turning them into different forms of tourist facilities, seems a possible way to be pursued for their recovery in a balanced connection with the traditional vocation and the environmental sustainability of the territory in which they are incorporated.

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MECHANICAL CHARACTERIZATION OF ADOBE BRICKS: ANCIENT CONSTRUCTIVE ELEMENTS FOR AN ECO-FRIENDLY BUILDING RENOVATION

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SUMMARY

Earth buildings have a strong connection with the environment, due to the local materials used and the specific techniques used. The current presence of ancient buildings models that involves raw earth, mostly in rural areas, is the result of countless trials methodologies employed in the local landscape that have allowed the creation of resisting constructions in the time. Along the Herculia Way, an ancient road dating back to the roman epoch, that connects the north to the south of the Basilicata Region (Southern Italy), there are many buildings realized with earth, particularly clay, wood and other natural materials.

A requalification and maintenance of these buildings and infrastructures could significantly contribute to the exploitation of rural tourism, aiming to support local economies of these areas that are mainly devoted to agricultural production. In these areas, an additional resource to be exploited for the local development is represented by the vernacular unused buildings, that could be restructured using the same natural materials, so respecting the local culture and landscape.

In order to identify the construction methods of these old buildings and the mechanical behaviour of their constructive materials, some laboratory tests on specimens taken from old adobe houses have been conducted in the laboratory of material testing of the SAFE School of the University of Basilicata. Compression tests were also conducted on two new specimens realized with a mix of clay and straw as well, in order to verify the differences between old and new adobe bricks. The new specimens were different between them for the disposition of the straw, respectively random and right-angled layers to the compression load.

The first results have shown that the compression strength is higher when the fibers are disposed in a regular way.

Key words: vernacular buildings, sustainable material, adobe bricks, mechanical characterization.

INTRODUCTION

Earth is an ancient building material that has been used in many different ways; a large part of the world's rural population still lives in earth buildings (North & Kanuka-Fuchs, 2008).

The interest in earth building construction is currently increasing by civil engineering, that seeks innovative ways to build. Construction materials, earth based, are the most commonly used in the world, since ancient time because they were considered economically attractive and environment-friendly (Akinwumi, 2014). They include sun-dried clay bricks, rammed earth, moist clayey soil mixed with straw, mud reinforced with timber etc.

In the territories that currently constitute the Basilicata Region (Southern Italy), there are many ancient buildings that were realized with these materials; in particular, their significant diffusion is registered along the *Herculia Way* and into the whole surrounding rural areas. The *Herculia Way*, dating back to the roman epoch and included in the "*Francigena*" Way, connected the town of Grumento with the "*Appia Way*" in the north, the "*Popilia Way*" and the *Ionian Coast* eastward (Fig. 1). It was an important road for the transportation of the agro-food products and goods produced in the current Basilicata and Apulia Regions, within these same Regions as well as towards other Italic and Mediterranean ports.

Within the rural areas crossed by this ancient route, men created the conditions for the construction of structures that could be used as shelter for both themselves and their animals. Since the territory was mostly dedicated to agriculture and there were not rocky areas in the immediate closeness, in order to build these structures, men used the local material that the surrounding area offered: wood, earth, clay and agricultural residues such as straw. All these easily available materials, characterized by good thermal and acoustic properties, are also usable and associable to simple constructive methods that require less energy.

Over time, these shelters have been abandoned due to the changes in lifestyle that since the end of the last century have affected the rural environments across Europe. In particular, two changes regarded the depopulation of the rural areas and the rapid spread of new constructive materials, as the concrete (Castro, 2009), influencing the agricultural environment and the visual perception of the landscape (Picuno, 2012).

The lack of maintenance caused their deterioration, leading to the irreversible loss of important forms of expression of cultural identities at local level, included the loss of construction method employing natural and available low-cost material.

At European level, the interest for the recovery of rural buildings is increasing; in particular, it is directed to respect the materials, recovery techniques and sustainability of the new actions, as well as to consider the relationship among these factors and the surrounding landscape (De Montis et al., 2013). Fortunately, many ancient buildings realized with raw earth have withstood the passing time and they are still perfectly integrated into the natural landscape, giving now the opportunity to study the construction material that was used at that time.

In Southern Italy, in some rural areas, it is possible to find earth buildings. Along the *Herculia Way*, that crosses the territory of *Sinni River valley* (Fig. 2) and in the lower

Valley of the Agri River (south of the Basilicata Region), there are buildings made with sun-dried adobe of blue-sandy clay mixed with straw, (Lista et al., 2013; Lista et al., 2012). Their presence in this area is due to the abundant availability of clay and the scarcity of stone (De Grazia, 2000). Some of these structures are still in good condition, while others need important and radical actions to be restored and re-used.

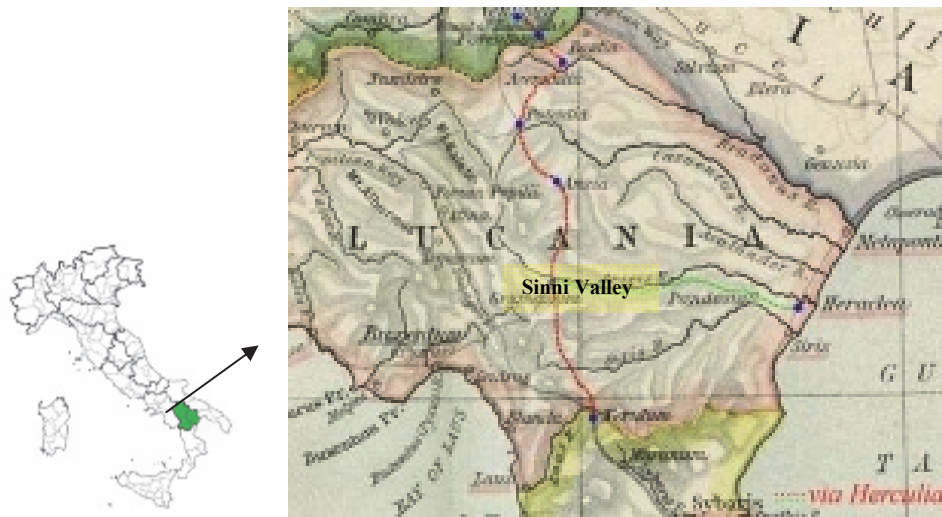


Fig. 1 Ancient map of the Basilicata Region, indicating the Herculia Way



Fig. 2 Sinni valley

The most interesting among these rural buildings, currently present, could be restructured by eco-friendly techniques, using the same natural materials in order to respect both the local culture and landscape. Since the management of the rural areas must always consider the importance of the agricultural activities to maintain their authenticity (Ayuga Téllez & García, 2002), these “new” vernacular buildings may become suitable places also for the exposition and sale of traditional food products, contributing to the exploitation of rural tourism and, consequently, supporting the local economies.

MATERIALS AND METHODS

With the aim to analyze these adobe buildings and to consider their most suitable requalification technique, in the present paper some particular examples of rural architecture (Fig. 3-4) were localized along two paths of the Herculia Way (Fig. 5). These buildings, now abandoned, made in the past with adobe bricks, were identified through *in situ* surveys, and considered in order to identify their construction method and the structural behaviour of their building material, whose mechanical characteristics were evaluated through experimental laboratory tests. The area investigated is located in the Municipality of Senise, south-east of the Basilicata Region, characterized by a geo-morphological conformation with valleys and plains. This area has an ancient farming tradition that is currently testified by the presence of ancient rural buildings, historically used for agricultural purposes. These structures were built about a hundred years ago, using sun-dried bricks (*Ciucioli*) made with locally available material, *i.e.* clay and straw. During time, the use of these materials has confirmed to be suitable to build constructions that are comfortable and durable. In fact, they have resisted to many and different weather conditions during centuries, in most cases without showing any structural failure.



Fig. 3 Adobe building in not good condition



Fig. 4 Adobe building in good condition

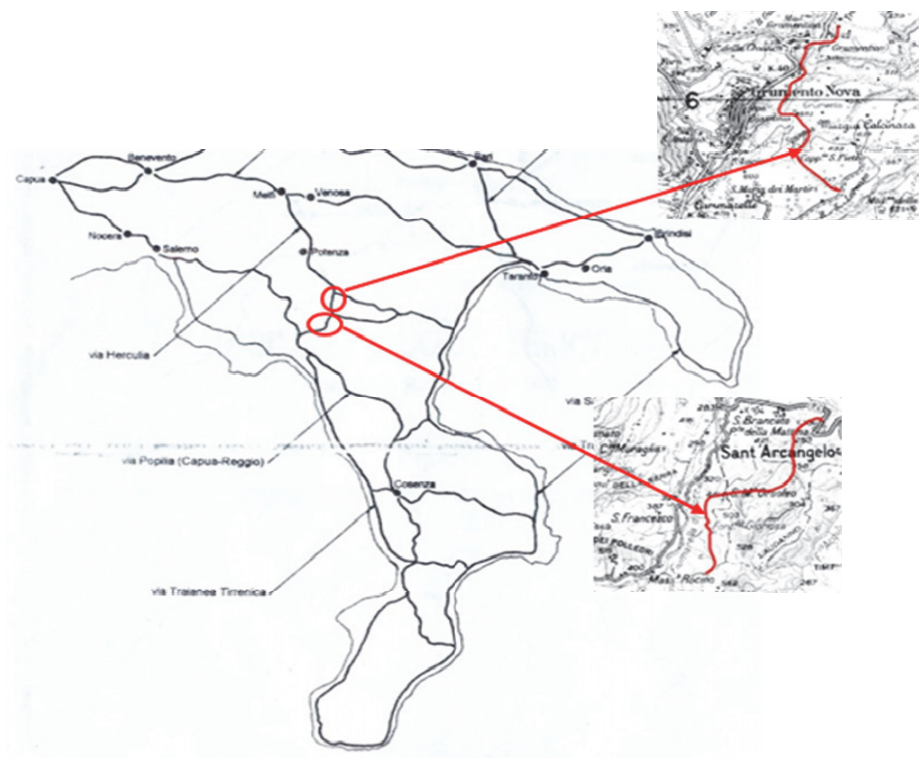


Fig. 5 The two identified paths of the Herculia Way stretch in the Sinigaglia valley

These vernacular buildings were locally called "Ciucioli", so adopting the same name used to indicate the single brick (Fig. 6).

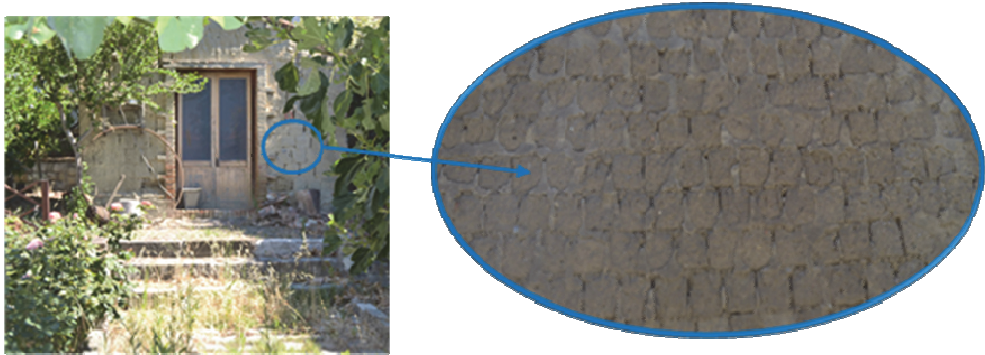


Fig. 6 Traditional vernacular building, called “Ciuciolo”, particular of the wall

In order to identify the construction methods of these old buildings and the mechanical behaviour of their constructive materials, some laboratory tests on three typologies of specimens have been conducted in the laboratory of material testing of the SAFE School of the University of Basilicata. The first typology was represented by bricks taken from old adobe houses while the other two consisted in bricks of new realization, different between them for the disposition of the straw, respectively random and right-angled layers to the compression load.

In order to realize these new earth bricks to be compared with the old ones, a quantity of clay was taken from the same Senise area, where anciently it was selected by local people for the construction of raw earth blocks. As the blocks were made of earth and straw, the wheat straw, included as a natural fibre within the new bricks, was also collected in the same Senise area, as well as the clay.

Into the laboratory, the threshed wheat straw was therefore cut to obtain fibres between 5 and 10 cm in length; then, clay and wheat straw, 33.3% of the total volume (Vega et al., 2011), were put in a large waterproof container, as follows:

- Typology A: a first earth layer has been created and covered by one layer of fibres, placing them in a random way in order to origin a multidirectional structure; then, water was added to moisten these two different materials. This procedure was repeated until the incorporation of all the volume of the materials.
- Typology B: a first earth layer has been created and covered by one layer of fibres, placing them in right-angled layers to the compression load; then, water was added to moisten these two different materials. This procedure was repeated until the incorporation of all the volumes of the materials.

The resulting masses were squashed, so obtaining an homogeneous material, and successively they remained drying for three days, in order to drain water in an homogeneous way.

After this period, twenty-four earth cubic blocks, twelve for each typology, having side equal to 15 cm, were manually prepared; therefore, they were placed to dry in a hot and ventilated place for four weeks.

The shrinkage of these new bricks was calculated measuring the dimensions of the samples after the drying process.

The compression tests (Fig. 7) were performed by using a computerized universal press machine Galdabini PMA 10 type. The breaking load was considered as the maximum load after which the specimen collapsed. Compression tests were performed on ten old adobe bricks directly extracted from existing ruined buildings, as well as twenty new ones (n. 10 of typology A and n. 10 of typology B) in order to evaluate and compare their strength at break.



Fig. 7 Compression test in progress on an “adobe” brick of the typology A

RESULTS AND DISCUSSION

The results of the compression tests on the adobe bricks are reported in Table 1.

Tab. 1 Results of the laboratory test

	Shrinkage (%)	Compression strength (N/mm ²)
Old brick	----	0,955
New brick: typology A	5	0,922
New brick: typology B	5	1,427

The shrinkage of the new bricks, happened during drying, was calculated by measurement of their dimensions, before they were subjected to the compression tests; for both typologies, shrinkage resulted on average limited within 5%.

The results of the compression test conducted on the two new different specimens realized into laboratory have shown that the compression strength is better when the fibers are disposed in a regular way, following right-angled layers in respect to the compression load.

The compression strength was similar for the old bricks and those of typology A, in average about 1 N/mm^2 , both lower than the average value of typology B.

The value of the old bricks confirms that they are characterized by a low strength, but it's worth to consider that it is an easily accessible materials, having low environmental impact and low cost for construction and maintenance, using the current technical and scientific knowledge.

Since the mechanical characteristics of the adobe blocks are strongly influenced by the fibres, which provide both tensile strength and shear strength, some blocks of this composite material with the addition of some other different fibres are going to be realized in order to verify the possibilities of improving their mechanical characteristics.

CONCLUSIONS

The analysis of the rural elements, observed along the tracts afferent to the Herculia Way into Basilicata Region, reveals the existence of an interesting cultural heritage; unfortunately, their abandonment means a loss of landscape unique resources. In an epoch in which the rural landscape is often subjected to planning policies dictated by different factors external to the agricultural world, the use both of the old constructive methodologies and of the local materials should be reconsidered. These materials are in fact characterized by low costs and reduced environmental impact; so, they would be the right "tools" to retrain these structures that lie along the Herculia Way.

The re-use of these rural buildings would also contribute to a limitation of the depopulation of these rural areas, so helping the local Authorities to create the conditions for their sustainable development; consequently, the reinforcement of the micro-economy would be fruitful for the local population and the whole Basilicata Region. The structural and functional requalification of the elements identified, could represent a real opportunity for the creation of new complementary activities aiming to the promotion of the development of sustainable rural tourism and of the local economy. According with their dimensions and in the respect of their original functions, the restructured buildings could be used in several ways: as traditional location for small and local craft and/or food selling, or simply showcases for local art and culture; exposition and tasting of typical local products; bed & breakfast; *etc.* In any case, the visitor/tourists travelling along the Herculia Way would have a definitive chance to immerse themselves into the nature and history of the territory.

ACKNOWLEDGMENTS

The Authors wish to thank Mr. Cosimo Marano of the SAFE School for his technical advice during the experimental tests.

The contribution to programming and executing this research must be equally shared among the Authors.

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GREEN ECONOMY AND ORGANIC AGRICULTURE: STATE OF THE ART IN THE ADRIATIC- IONIAN AREA

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ABSTRACT

The organic agriculture is defined, by the Codex Alimentarius Committee, as a holistic management system that promotes and enhances agro-system health including biodiversity, biological cycles and soil biological activity. It prohibits the use of chemical drugs, fertilizers and pesticides. Thus the agricultural sector, as a whole, plays an important role in shaping the transition towards a greener economy, with a high number of agricultural companies. During the last years, the agricultural companies have been investing considerable resources on reducing consumption of energy; they have also been strongly committed to organic farming. The number of organic products and companies has grown considerably contributing significantly also to the export performance.

The objective of this paper is to define a Green Innovative Development and to identify the economic sectors where Green Business Innovation can be applied, comparing the current state of art and the policy frameworks in the cross-border area Italy-Greece. It is based on a more extensive study prepared within the context of a project performed at trans-national level, co-funded by the European Union within the framework of the Cross-border Cooperation Program "Greece – Italy 2007-2013".

Two groups have conducted field researches, data collection as well as interviews with stakeholders. Data regarding the agricultural sector have been extrapolated and here reported. The current situation in this field within the eligible territories in Greece and in Italy are described and discussed. This project will significantly contribute to establish and enhance cross-border cooperation networks, playing an important role in bringing people and

institutions together, as to develop a common understanding of development problems, challenges and solutions.

Key words: *Green economy, organic farming, agriculture*

INTRODUCTION

The paper is a part of a more extensive study prepared within the context of the project “Green Business Innovation – Developing innovative entrepreneurship through green economy applications and human resource training on green jobs in the cross- border area- From a general definition of the Green Economy to the “green” offer and demand side, it shows the current situation in this field in the two eligible areas of the program.

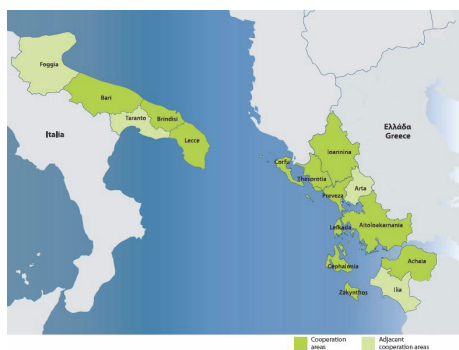


Fig. 1 Eligible Territories Greece - Italy

The eligible territories for Greece are the prefectures of Aitoliaakarnania, Ilia, Achaia, the Ionian Islands Kerkyra/Corfu, Lefkada, Kefallinia/Cephalonia, Zakynthos and the Epirus Region (Ioannina, Preveza, Thesprotia) and for Italy the Puglia Region (Fig 1).

As a methodological approach, two groups formed from ARTI–Regional Agency for Technology and Innovation of Puglia Region and from the Division of Management and Organization Studies in the Department of Mechanical Engineering and Aeronautics of the University of Patras, have conducted field researches, data collection as well as interviews with stakeholders. Data regarding the Agricultural sector extrapolated and reported here.

OVERVIEW OF THE LEGISLATION FRAMEWORK AND CERTIFICATION BODIES

The regulations approved by the European Council of Ministers of Agriculture govern the guidelines and objectives to be pursued through organic production. The legislation framework aims to promote the development of organic agriculture as a sustainable farming method promotes biodiversity and animal welfare,

“The term "organic" is allowed only if 95% of the agricultural ingredients come from organic production. In addition, the code number of the inspection body responsible is

indicated on the label. Since 1 July 2010 the packaged organic products must bear the EU organic logo and the place of production, allowing them to be easily recognized by consumers”.

The main regulation in a European and National level

- Commission Regulation (EU) n°834/2007: on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91.
- Commission Regulation (EU) No 889/2008: laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control.
- Commission Regulation (EU) No 1235/2008: laying down detailed rules for implementation of Council Regulation (EC) No 834/2007 as regards the arrangements for imports of organic products from third countries.
- Commission Regulation (EU) No 271/2010: amending Regulation (EC) No 889/2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007, as regards the organic production logo of the European Union.

The national regulatory framework of the two territories of the study regulated the production and labelling of organic products by implementation actions of CE rules.

Moreover the Puglia Region with the deliberation of the with Regional Council n. 1706/2010 has approved the measures for the online notification of the method of organic farming by the farmers via the portal " Biobank Open Project".

The Biological Certification system of the two territories

Those who cultivate, breed, prepare and import organic products must comply with the provisions in the EEC Regulation 2092/91 and subsequent amendments and additions. To this end, the regulation required the Member States to establish an inspection system operated by one or more designated authorities and/or private bodies recognized by a single authority.

The Italian State has implemented the European regulation with the Legislative Decree no. 220/1995 and Ministerial Decree no. 91436 of 4/8/2000 and the Ministerial Decree of 29/03/2001.

For this purpose, most of the Certification Bodies (ODC: organismi di controllo) authorized in Italy submitted for the accreditation approving to SINCERT, the Italian National Accreditation Body appointed by the State to perform accreditation activity. It is an accreditation body under the International volunteer system, which presides application of the ISO rules. The Italian Ministry of Agriculture is the Authority responsible for the accreditation of Inspection and Certification bodies. The certification bodies operating in the Puglia Region are shown in table 1

In Greece the Ministry of Rural Development and Food has established a system for the monitoring and certification of products with the appropriate Office of Organic Agriculture while the role for the supervision has entrusted to the Agricultural Products Certification and Supervision Organization (OPEGEP) AGROCERT (Tab.2)

Tab. 1 Certification Bodies in Puglia

BIO AGRI CERT	
ICEA - Istituto per la Certificazione Etica e Ambientale	
SIDEL SPA	
Suolo e Salute srl	
CCPB S.r.l. -	
CODEX S.r.l.	
EcoGruppo Italia S.r.l.	
BIOS	
FEDERBIO	
QC&I	
VALORI ITALIA	

Tab. 2 Authorized Bodies in Greece

PHYSIOLOGIKE		COSMOCERT	
QWAYS		Q-CHECK CERT	
QCERT		TUV AUSTRIAN HELLAS	
A CERT		DIONET	
IRIS BIO		GREEN CONTROL	
OXYGEN CERT		BIO-GEOLAB	
GM Cert		BIO HELLAS	
EUROCERT		TUV HELLAS	

In the second half of the '90, the organic growth in Puglia had a setback due to the crisis within the sector itself, together with the unavailability of Regional and European funds. After a period of near stability, in 2009 the sector recorded a slight growth until the years 2012 - 2013 when reaches a significant increase both in terms of operators and of the surface cultivated with biological method. This growth is also attributable to the increase of the public awareness and to the availability of regional funds for the organic farming; (Fig. 1).

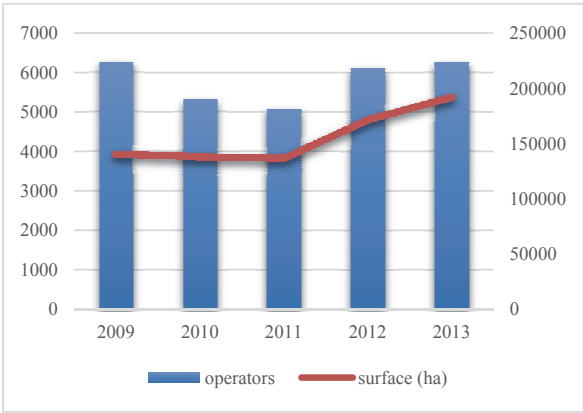


Fig. 1 Organic evolution in Puglia Region

The Regional Administration supports the organic farming with a series of targeted interventions such as “the Rural Development Plan” which by the action on Organic Agriculture provides incentives for Agri-food business. It considers that the organic farms may contribute to the revival of agriculture, a key sector of the Apulian economy. In this period, the organic farming in Puglia has developed such a qualitative and a quantitative dimension that located it among the first places both at national and international level in terms of the cultivated area and numbers of bio-operators.

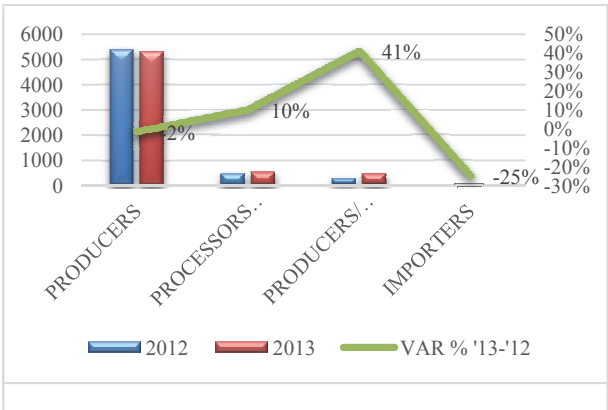


Fig. 2 Operators and % variation

Based on the data available on December 31st 2013 the results show that the organic operators in Puglia are n.6254 of which: n.5289 producers only; n.513 processors (including companies that carry out retail activities); n.444 engaged in production and processing; n.8 importers only or importers engaged in production or process activities (Fig 2).

Comparing the data with those related to the previous year (2012), it appears an increase of 2,3% of the total number of certified operators. The distribution of operators on the National ranking shows Sicily, Calabria and Puglia among the regions with the highest presence of organic farms (18,8%,13,6% and 12% respectively).

The related area, in conversion or fully converted to organic agriculture, has reached 191.791 hectares, with an increase of 12,1% compared to 2012, a value almost equal to the national one (12,8%). In fact, Puglia occupies the second place after Sicily in a regional ranking based on the organic farming surface.

Olives, along with cereals and forages represent the main farming system, covering more than 60% of the total organic surface. It follows, in order of importance, the vineyard crop (Fig.3).

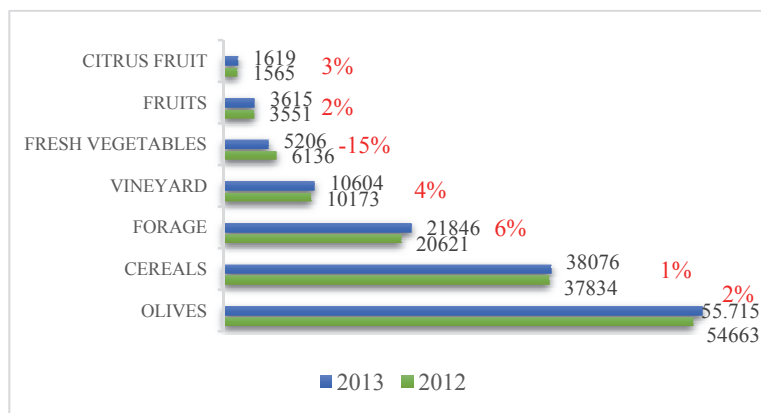


Fig 3 Main organic Cultivations in the Puglia Region (figures in hectares)

In the past, the organic livestock in Puglia had a negligible role. However, during the last year the region has recorded a surge in the number of livestock farms, i.e. from n.28 companies in 2011 to n.117 by 2012. Therefore in terms of percentage variation, the region has registered a value of 318%, compared to 2011, which places it in the first position at a national level (Fig. 4,5).

The organic aquaculture is still a niche market within the organic farming but with a great potential and of particular interest especially in terms of environmental sustainability. The data on a national level provided by SINAB show a consistency of n.17 plants at the end of year 2013 (Fig.6).

These plants are located in only seven of the twenty Italian regions. In Europe, there is a growing interest of the consumers for bio-fishery product; however, this situation is currently not the case in Italy.

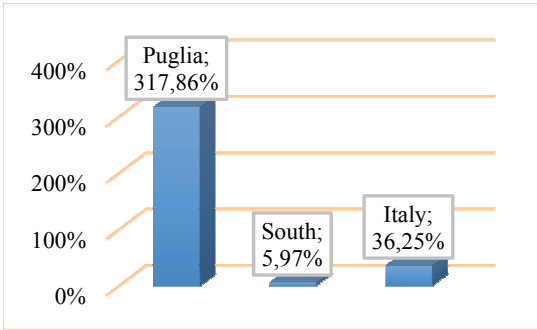


Fig. 4 % variation '11-'12 of organic livestock farms

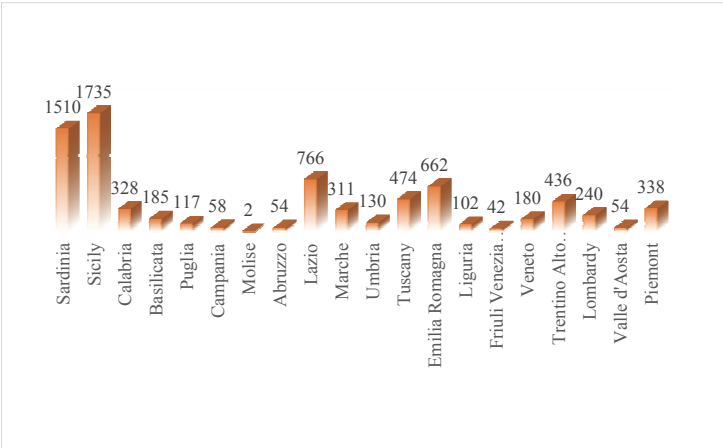


Fig 5 N° Organic Livestock Farms by Region – 2012 Source SINAB

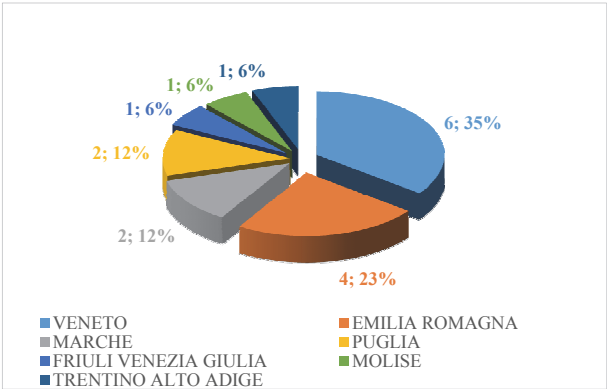


Fig. 6 Organic aquaculture (n° and percentage) Source SINAB

In fact the discrete potential demand on the foreign front, do not seem to be comparable on the domestic market, still not aware in terms of organic fish consumption. Both at National level and particularly in the Region, this sector must be supported, enhanced and retrained thanks to the organic certification, of the existing aquaculture facilities, constructed on an old concept of conventional farming, that did not always embrace the concepts of animal welfare and environmental sustainability.

The opportunities that the green economy offer to the Puglia territory are mainly connected with the specific geographical location, cultural tradition and social and economic reality of Puglia which is one of the biggest region in South Italy. The local socio-economic structure historically based on the agricultural and food sector gives many interesting opportunities for organic production at high production levels. The archaeological and cultural heritage of the region rises many interesting opportunities for a sustainable tourism too.

Statistical data of the organic farming in the country in Greece, resulted from the processing of the data of the Ministry of Rural Development and Food where on 31 December of each year the Audit and the Certification Bodies of biological products must provide.

Other data derived from Eurostat and the International Organizations of Organic Agriculture (IFOAM, FIBL and others). Thus, it became possible to present the most recent figures of the organic agriculture and animal production as in the web site of the Ministry the summary data of the country was updated up to 2013. For the description of the single Governmental Regions situation, the year 2009 is taken as reference, as there are no official disaggregated data for the following years.

In Greece, thanks to the mild weather conditions, the low-level agrochemical pollution and the small size family-farms, the organic farm represents a challenge.

During 2012 the area of organic agriculture in Greece stood at 12,5% (including pastures) of the total cultivated area, 3.676.610 ha. In the organic agriculture sector, are active n.23541 companies while n.382.606 ha are organic surfaces (croplands, pastures), in the transitive and complete biological stage (Fig.8,9).

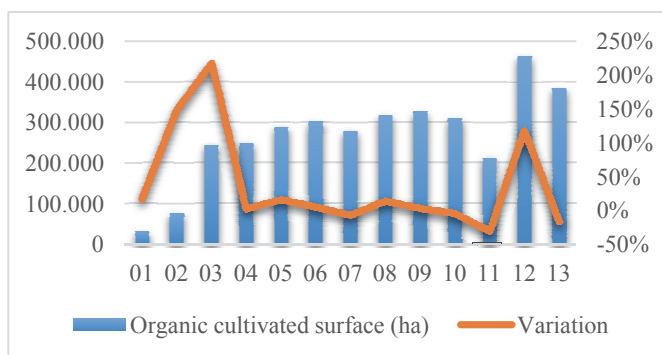


Fig. 8 Total Organic surface + pasture land

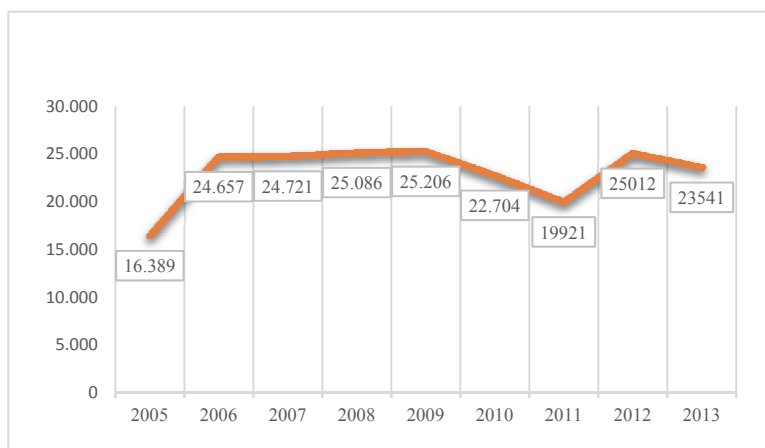


Fig. 9 Development of Organic Farming in Greece

The highest percentage of organic areas is concentrated in the cultivation of cereals, permanent grazing, fodder crops and olives with values of 36,5%, 14,8%, 21,8% and 18,5% respectively and referred to a total of 242.300 ha of cultivated surface except pasture land and fallow. Total surface cultivated by biological methods on 2013 was 242.323,05 ha, pastures and fallow areas don't included (Tab. 3).

Tab. 3 Main biological crops in Greece

Type of cultivation	Cultivated Area (Ha)	% vs total cultivated area
Cereals	88.426,94	36,49%
Industrial crops	4.740,21	1,96%
Fresh vegetables	1.392,83	0,57%
Vegetables	4.668,84	1,93%
Fodder	35.929,10	14,83%
Edible roots	248,96	0,10%
Other	844,63	0,35%
Permanent grazings	52.961,46	21,86%
Other fruits	674,31	0,28%
Tropic fruits	1.360,26	0,56%
Citrus fruit	1.388,69	0,57%
Grapes	4.717,83	1,95%
Olives	44.948,49	18,55%
Other perennial cultivations	20,50	0,01%

Source. Minister of Rural Development and Food

The last years, the organic livestock farming rather than availability, has presented a fluctuating trend. In fact, between 2009 and 2011 the sector shows a declining trend in the production of all kinds of animals, while from the end of 2011 it registers an increase and in particular, these values are more than doubled in goats, cattle and sheep. There is only a decrease in pigs production, continuing the negative trend from 2009 (Fig. 10).

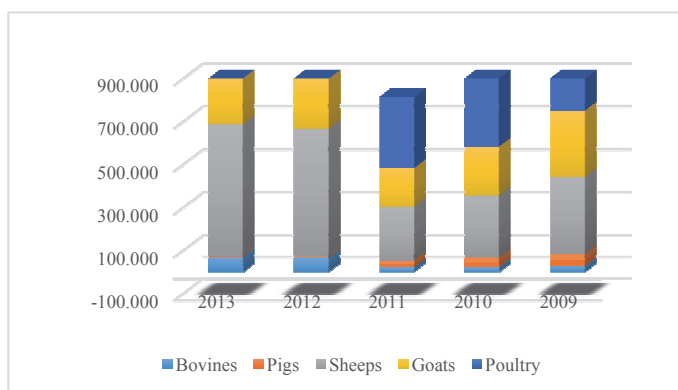


Fig. 10 Organic Livestock evolution in Greece

Tab. 4 Operators in Regional ranking and % of organic surface

Regions	Units	Producers	Processors	%	Organic surface %
Western Greece	4464	4363	101	18,7	6,08
Epirus	503	480	23	2,1	0,92
Ionian Islands	291	271	20	1,2	0,83
TOTAL GREEK GBI REGION	5258	5114	144	22,0	7,83
Peloponnese	3834	3520	314	16,1	13,6
Thessaly	3365	3273	92	14,1	13,5
Central Macedonia	2754	2629	125	11,6	29,3
Northern Aegean	2514	2429	85	10,6	10,1
Crete	2071	1858	213	8,7	5,9
Central Greece	1456	1399	57	6,1	6,6
Eastern Macedonia, Thrace	1438	1383	55	6,0	7,9
Western Macedonia	720	695	25	3,0	3,6
Attica	335	187	148	1,4	1,5
N. Aegean	81	70	11	0,3	0,3

Source: <http://it.opeekepe.gr/aggregate/>

This chapter is focused to the Greece-Italy eligible area, which is the main object of the study. The organic farmers of these territories rank first in the country. Organic agricultural products have increased significantly in the last 10 years, while important is the list of agricultural products the Region produces over 10% of domestic production in some near or above and 20% of domestic production, and it has many products export-oriented, as for example strawberry, watermelon, vegetables, etc.

The outlook is positive for the growth and qualitative improvement of primary products of these Regions, in aquaculture, agricultural products and livestock. Aquaculture is one of the main export industries with exports to many countries around the world. The area shows great progress in research and innovation at international level (Tab.4).

The main organic crops in Greek GBI Region according to a research of OPEKEPE in 2010 in descending order are: Dominant organic farming remains the cultivation of olives; Cereals (wheat, barley, oats, maize, etc.); The hay plants (annuals, perennials, pasture); Other arable crops; Industrial plants; Fruit for forage; The vine; Fruit trees; Citrus.

In animal production in organic livestock, active in 2007, there were n.1.846 producers – farmers. There is not available data in the coming years and to date. In 2010 there were n.950.268 organically reared animals (not counting the cells): Cattle; Sheep Goats; Pigs; Poultry; Beehives.

The organic sector in the study areas, presents a very interesting profile and is constantly changing, with a high growth potential. The technique of organic farming determines benefits both to the environment and to the market improving and strengthening the international competitiveness of the two territories. Evidently, organic agriculture must contribute to achieve the goals that according to the guidelines of the Codex Alimentarius are:

- enhance biological diversity within the whole system;
- increase soil biological activity;
- maintain long-term soil fertility;
- recycle wastes of plant and animal origin in order to return nutrients to the land, thus minimizing the use of non-renewable resources;
- rely on renewable resources in locally organized agricultural systems;
- promote the healthy use of soil, water and air as well as minimize all forms of pollution thereto that may result from agricultural practices;
- handle agricultural products with emphasis on careful processing methods in order to maintain the organic integrity and vital qualities of the product at all stages;
- be established on any existing farm through a period of conversion, the appropriate length of which is determined by site-specific factors such as the history of the land, and type of crops and livestock to be produced.

DISCLAIMER

This report has been realized within the project “Green Business Innovation”, co-funded by the European Union (ERDF) and National Funds of Greece and Italy under the European Territorial Cooperation Programme (Greece – Italy 2007-2013). The views expressed in this publication do not necessarily reflect the views of European Union.

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ZNAČAJKE AGROTURISTIČKE POTRAŽNJE STANOVNIKA GRADA ĐURĐEVCA

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SAŽETAK

Turizam je jedna od najvažnijih gospodarskih grana Hrvatske. Osim „morskog“ turizma koji je najvećim dijelom odvija u nekoliko ljetnih mjeseci, posljednjih godina sve veći je posjet inozemnih i domaćih turista kontinentalnim destinacijama Države. Ruralni a posebice agroturizam privlači sve veći broj posjetitelja te je često ne samo dopunjujući segment turističke ponude nego i dominantan u dohotku obiteljskih poljoprivrednih gospodarstava. Na taj način on postaje pokretač i poljoprivrednog razvitka.

U radu se istražuje postojeća i buduća agroturistička potražnja stanovnika grada Đurđevca na ruralnom prostoru Grada. U radu se pošlo od pretpostavke da su turistički resursi nedovoljno valorizirani te da je ukupna pa i agroturistička ponuda relativno skromna, a cilj rada je ustanoviti agroturističku potražnju stanovnika Grada Đurđevca i njihove stavove prema određenim elementima agroturističke ponude.

Za potrebe rada provedena je anketa na slučajnom uzorku od 153 ispitanika s područja grada Đurđevca. Istraživanje je pokazalo da postoji značajan interes za odlazak na agroturističko gospodarstvo i to u proljeće i jesen. Anketirani smatraju da je za poboljšanje agroturističke ponude nužno povećati ukupnu turističku ponudu koju treba kvalitetnije promovirati, ali i povećati međusobnu suradnju županijskih i gradskih turističkih zajednica te zainteresiranih poljoprivrednih proizvođača.

Ključne riječi: *agroturizam, potražnja, Koprivničko-križevačka županija, grad Đurđevac*

UVOD

Turizam je jedna od najstarijih pojava u razvitku civilizacije jer su ljudi oduvijek putovali zbog egzistencijalnih, bioloških, ekonomskih i/ili osobnih potreba odnosno zadovoljstva. Tako o turizmu možemo govoriti kao o najvećoj migracijskoj pojavi današnjice (Vukonić, 1987). Veliki poticaj razvitku turizma bio je razvitak prometa te porast dohotka gdje turistička potrošnja postaje sastavnicom osobne i potrošnje na razini kućanstva. Danas je turizam priznat kao ekonomska aktivnost globalnog značaja. Kako je važnost turizma rasla, tako je sve veća pozornost turizmu dana od strane vlade, organizacija u javnom i privatnom sektoru, ali i u teoriji (Dulčić, 2006).

U Republici Hrvatskoj (RH) turizam predstavlja jednu od najvažnijih gospodarskih grana čemu je pokazatelj porast broja dolazaka i noćenja stranih i domaćih turista, ali i njegov udjel u ukupnom BDP-u. Maritimni turizam je dominantni oblik turizma u Hrvatskoj, ali je sve značajnija potražnja za ponudom kontinentalnog turizma. U tome je značajan ruralni turizam, a u njemu je jedan od njegovih najzahtjevnijih oblika - agroturizam (Grgić i sur., 2011).

Zbog porasta značenja agroturizma, sve više autora istražuje čimbenike ponude i potražnje i to najčešće vezano za određena područja odnosno destinacije. Zrakić i sur. (2012) istražuju agroturističku potražnju na području Istarske, Međimurske, Koprivničko-križevačke i Zagrebačke županije. Kod agroturističke ponude, prosječno visokom ocjenom ispitanici vrednuju smještaj, hranu, gostoljubivost domaćina te krajobraz, ali i naglašavaju nedostatak drugih sadržaja kao što su sport i kultura. Nasuprot tome, Tubić (2013) kao veliko ograničenje budućeg razvoja agroturizma u Osječko-baranjskoj županiji navodi nedovoljnu obučenosť osoba na agroturističkim gospodarstvima za obavljanje turističke djelatnosti.

Vrlo često su agroturisti osobe s posebnim prohtjevima i Grgić (2008) ih definira kao *ljubitelje prirode, žitelje grada, osobe sklonu selu i starim običajima, starije osobe koje preferiraju prirodu i zdravu hranu odnosno osobe željna mira*. U istom radu i većina ispitanika (88,3%) prosječnog agroturista okarakterizirali su kao osobu „vezanu“ uz prirodu, selo i njegove tradicijske običaje te životinje, osobe sklone zdravom načinu života, stanovnici gradova željni mira i tišine.

MATERIJAL I METODE

Rad se temelji na rezultatima istraživanja provedenom na području Grada Đurđevca. Anketa je provedena 2012. godine metodom intervjua „face to face“. U radu se pošlo od pretpostavke da su turistički resursi nedovoljno valorizirani te da je ukupna pa i agroturistička ponuda relativno skromna. Cilj rada je ustanoviti agroturističku potražnju stanovnika Grada Đurđevca i njihove stavove prema određenim elementima agroturističke ponude. Zbog nerazvijene agroturističke ponude na istraživanom području, pojedina pitanja postavljena ispitanicima se odnose na cijelu Županiju. Prema Bosnić (2011) u Koprivničko-križevačkoj županiji je registrirano 6 agroturističkih gospodarstava s 22 kreveta.

Za potrebe rada provedena je anketa na slučajnom uzorku od 153 ispitanika – potencijalna korisnika agroturističkih usluga na području grada Đurđevca. Ispitanici su morali biti

punoljetni te nisu smjeli biti iz istog kućanstva. Anketa je sadržavala 18 pitanja od kojih je 5 bilo otvorenog tipa, a ostala su bila s ponuđenim odgovorima – zatvorenog tipa. Za obradu podataka iz ankete korišten je SPSS (*Statistical program for Social Sciences 17.0*). Utjecaj određenih obilježja ispitanika na mišljenje o agroturizmu ispitan je korištenjem hi-kvadrat testa i t-testa ($p < 0,05$).

REZULTATI I DISKUSIJA

Koprivničko-križevačka županija (KKŽ) smještena je u sjeverozapadnom dijelu Hrvatske. S površinom od 1.748 km² sedamnaesta je po veličini županija u Hrvatskoj, dok je po broju od 115.582 stanovnika - šesnaesta (Službene stranice Koprivničko-križevačke županije, <http://www.kckzz.hr/o-zupaniji>, pristupljeno 18.07.2012.).

U ukupnim površinama značajan dio su obradive (44%) te površine pod šumama (33%).

Poljoprivredno stanovništvo Županije ima obilježja ratarsko-stočarskog proizvodnog tipa te je proces industrijalizacije uvjetovao njenu transformaciju iz tradicionalne agrarne u važnu industrijsko-poljodjelsku županiju (Čurić, 1997).

Grad Koprivnica je administrativno-upravno i gospodarsko središte Županije, a svojim središnjim prometno-geografskim položajem i najsnažnijim gospodarstvom ima vodeću ulogu među 20 općina, dok je grad Đurđevac, uz Križevce, nositelj gospodarskog i drugog razvitka.

Grad Đurđevac je položen uz Podravsku magistralu koja povezuje Varaždin i Osijek te predstavlja čvorište magistrale prema Bjelovaru i Zagrebu. Nizinom rijeke Drave, kroz Đurđevac prolazi i pruga koja spaja Osijek, Koprivnicu i Zagreb. Danas je Đurđevac udaljen nepunih sat i pol vremena vožnje automobilom ili vlakom od Zagreba, a manje od pola sata vožnje od Koprivnice, Bjelovara i Virovitice a do graničnog prijelaza s Mađarskom potrebno je petnaestak minuta. Đurđevac sa svojom okolicom, zbog svog geografskog položaja i gospodarskog stanja, ima prvenstveno stambenu i rekreativnu funkciju (Drava i Bilogora). Blizina većih gospodarskih središta čini ovaj prostor atraktivnim za život, odmor i rekreaciju jer nema većih industrijskih pogona, krajobraz je očuvan, a naseljenost slaba.

Turistička je ponuda na području grada Đurđevca relativno skromna i duži niz godina svodi se na tradicionalnu kulturno-povijesnu turističku manifestaciju *Picokijada*, čija se *Legenda o Picokima* nalazi u Registru kulturnih dobara Ministarstva kulture RH, kao zaštićeno nematerijalno kulturno dobro. Za isto je grad Đurđevac u kategoriji „Turizam i lokalna nematerijalna baština“ 2008. godine od strane Europske destinacije izvrsnosti (EDEN) primio nagradu za Europsku destinaciju izvrsnosti. Značajnija manifestacija, osim *Picokijade*, je i *Đurđevo* koje se obilježava kao proslava dana grada Đurđevca, za čije se vrijeme održava i festival dječjeg glazbenog stvaralaštva *Kukuricek*.

Područje Grada Đurđevca ima obilježja ruralnog područja, koje je turistički neiskorišteno, te se kao jedan od oblika turističke ponude nameće razvitak agroturizma. Agroturizam potrošačima nudi povijest, ugođaj i proizvod prostora koji se razlikuje od agroturističke ponude drugog prostora (Grgić i sur., 2011). U ekonomskom smislu, agroturizam podiže razinu zaposlenosti i dohodak stanovnika ruralnog prostora.

Socio-demografska i ekonomska obilježja ispitanika

Značajna je veza između socio-demografskih i ekonomskih obilježja osoba i (agro) turističke potražnje i potrošnje. To su spol, dob, obrazovanje te vrsta zaposlenja i visina dohotka koji se najčešće promatraju kao varijable koje utječu na potražnju/potrošnju.

Od 153 ispitanika veći dio su bile žene (84 odnosno 54,9%), a prosječna dob ispitanika bila je 34 godine (od 18 do 60 godina). Prosječan broj članova kućanstva je bio 3,8. Spolna struktura uzorka je slična spolnoj strukturi stanovništva područja pa i Hrvatske. Isto je i sa veličinom odnosno brojem članova kućanstva. Jedino je prosječna dob „povoljnija“ što nam je u istraživanju bilo prihvatljivo jer su osobe te dobi znatno samostalnije (ekonomski, transportno, spoznajno i slično) od znatno mlađih ili starijih.

Većina ispitanika je srednjoškolski obrazovana (60,8%), 13,7 % ispitanika završili su višu školu, 21,6% je fakultetski obrazovano, dok 3,9% ispitanika ima završenu samo osnovnu školu.

Najveći dio ispitanika (30,7%) je iz kućanstava sa do 5.000,00 kn ukupnog mjesečnog prihoda, a najmanji iz kućanstava sa više od 15.001,00 kn (3,9%).

Agroturistička potražnja i turistička kretanja ispitanika

U Hrvatskoj je uobičajeno korištenje određenog broja dana za boravak izvan kućanstva i mjesta boravka te većina zaposlenih za to koriste godišnji odmor, uzdržavani školske odmore, umirovljenici kao „pratnja“ djeci/unucima. Razlog tome je tradicija ali i veliki broj stambenih jedinica u vlasništvu kako na moru tako i na kopnu.

Kao najčešću vrstu godišnjih odmora i jednodnevnih izleta, naši ispitanici navode ljetovanje (69,9%), manje zimovanje (5,9%) te najmanje njih odabire agroturizam (3,3%). Nakon ljetovanja, većina ispitanika odlazi na kratke izlete u trajanju od 1 do 3 dana (37,9%).

Ispitanici svoje slobodno vrijeme na odmoru provode u upoznavanju i razgledavanju prirodnih (53,6%) i kulturnih znamenitosti (37,9%) te manje u „konzumaciji“ drugih sadržaja.

Kao najbolji i najčešći oblik informiranja vezan za odmor ispitanici koriste Internet (62,1%) i prema spolu postoji statistički značajna razlika među skupinama ($\chi^2 = 9,420$, $p = 0,009$) kao i veza između obrazovanja i informiranja putem Interneta ($\chi^2 = 15,950$, $p = 0,003$). Internet više koriste nešto više muški ispitanici (za 3%) te osobe više razine obrazovanja (74% od ukupno ispitanih više ili visoko obrazovanih ispitanika).

Osim informacija Internetom, ispitanici se pouzdaju u preporuke poznanika (51,6%) i to je preporuka kojoj najviše vjeruju. Manje ispitanika koristi prospekte (26,8%), izvješća i reklame u medijima (18,3%) te putničke agencije (9,2%), dok 11,1% ispitanika uopće nema potrebu za informacijama o dodatnim sadržajima tijekom odmora.

Veliki dio ispitanika (71,9%) bi godišnji odmor proveo na agroturističkom gospodarstvu pri čemu manji dio sigurno (26,1%), a 45,8% vjerojatno. Zabilježena je statistički značajna razlika između muških i ženskih ispitanika ($F=6,156$, $p=0,014$). Od ukupno ispitanih 69 muških ispitanika njih 78,3% bi svoj godišnji odmor proveli na agroturizmu, dok bi isto to učinilo 66,7% ženskih ispitanika (odgovori sigurno i vjerojatno bih).

Najčešće prihvatljivi oblici posjeta agroturističkim gospodarstvima su u obliku jednodnevnih i vikend izleta i to u proljeće, dok je boravak dulji od 5 dana u zimi najmanje poželjan.

Tablica 1 Odabir godišnjih doba i vremenskog perioda trajanja boravka na agroturističkom gospodarstvu

Table 1 Season selection and duration of staying at agro-touristic farm

Godišnja doba	Vremenski period				Nikad (%)
	Jednodnevni izleti (%)	Vikend (%)	Do 5 dana (%)	Više od 5 dana (%)	
Proljeće	45,8	45,1	16,3	5,9	13,1
Ljeto	22,2	35,5	24,2	11,8	28,1
Jesen	31,4	35,9	16,3	7,8	28,1
Zima	26,1	26,1	12,4	6,5	38,6

Izvor: Anketa: Agroturistička potražnja stanovnika grada Đurđevca

Source inquiry: Agrituristic demand of Đurđevac inhabitants

Ovakva redistribucija potražnje je logična jer su agroturistički posjeti najčešće obiteljski, grupni i zbog mnoštva ograničavajućih čimbenika prihvatljivi tijekom vikenda odnosno praznika. Dulji posjeti i to ljeti su, kao kod većine stanovnika Hrvatske, određeni za destinacije uz morsku obalu.

Potrošači su sve izbirljiviji i kritičniji prema vrsti i kvaliteti ponude. Iako su neki elementi ponude zajednički za sve oblike turizma, mnogi istraživači ističu da je agroturizam zahtjevniji te da se od njega često očekuje „nešto više, posebno, iznenađujuće.

Tablica 2 Ocjena važnijih sadržaja ponude u Koprivničko-križevačkoj županiji (1-jako loše; 5-jako dobro)

Table 2 Grades of important offer content in Koprivnica-Krizevci county (1- very bad; 5- very good)

Sadržaj	N	Minimum	Maximum	Mean	Std. Deviation
Smještaj	146	1	5	3,25	0,914
Hrana	146	1	5	3,92	0,990
Priroda	146	1	5	4,29	0,879
Uređen okoliš	146	1	5	3,58	0,837
Gostoljubivost domaćina	146	1	5	3,76	0,964
Mogućnost bavljenja sportom	146	1	5	3,16	0,987
Kulturne manifestacije	146	1	5	3,18	1,044
Ostali sadržaji	34	1	5	3,15	1,306

Izvor: Isti kao za Tablicu 1

Source: Same as Table 1

I u ovom istraživanju ispitanici su najviše vrednovali prirodu (4,29), gastronomsku ponudu (3,92) te gostoljubivost domaćina (3,76) što je potvrda specifičnosti agroturističke ponude koju možemo iskazati kao „ponudu autohtonih proizvoda u prirodnom okružju ponuđenih sa osmijehom“. Često se ona poistovjećuje sa „ugodajem davno napuštenog doma“ te je to za mnoge i „povratak korijenima“. Iako postoje razlike u visini ocjena, redosljed je sličan kao i kod nekih drugih istraživanja (Grgić 2008).

Ponekad se kao jedan od razloga neposjećivanja određenih mjesta odnosno manifestacija navodi „nedostatak vremena“ odnosno njihova udaljenost od mjesta življenja. Razvitak prometnica i posjedovanje prometala „dovele su destinacije u dvorište“. Najveći dio ispitanika (38,6%) prihvatljivom udaljenošću destinacije smatra onu koja se nalazi na između pola sata i sat vožnje, zatim udaljenost na manje od sat vožnje (17,0%) te udaljenost na više od sat vožnje (7,2%), a veliki dio (37,3%) ispitanika smatra da udaljenost nije važna. Ne postoji statistički značajna razlika između muških i ženskih ispitanika ($F = 2,149$, $p = 0,146$) s obzirom na prihvatljivu udaljenost agroturističkog gospodarstva jer su danas podjednako „mobilni“ ali i kao se radi o „obiteljskoj potražnji“ zajedno je i posjećuju.

Skoro polovica (47,7%) ispitanika smatra da je ponuda agroturističkih usluga u Županiji slaba te njih 19,0% da je gotovo nikakva. Većina ih (41,2%) smatra da agroturističke usluge u Županiji najviše koriste stanovnici drugih županija, inozemni gosti (17,0%) te domicilno stanovništvo (11,8%). Struktura odgovora je dobra podloga za promišljanje razvitka agroturizma i strukture ponude s obzirom na preferencije potrošača.

Agroturistička ponuda kvalitetom ali i cijenom treba odgovoriti na zahtjevnost potrošača koji su „ciljano došli, očekujući puno za što manje novaca“ i koje često promišljaju da si „proizvodi agroturističke ponude sami po sebi jeftini“. Prosječna prihvatljiva vrijednost noćenja s doručkom po osobi je oko 150 kn pri čemu najveći dio ih je voljan platiti do 100 kn. Prosječna prihvatljiva vrijednost objeda po osobi je oko 70 kn odnosno za najveći dio njih (30,1%) je to do 50 kn. Ponuđači agroturističkih proizvoda i usluga u budućnosti trebaju ići na „ciljani dio potrošača“, vrstom i cijenom, u čemu će im od pomoći biti i ovakva istraživanja.

Već uočena slaba agroturistička ponuda kao i nepoznavanje same ponude na istraživanom području mogla bi se popraviti promocijama i reklamama (85,4%), odnosno dobrim marketingom, povećanjem ponude, podrškom države, županija, gradova i ostalih samoupravnih jedinica putem poticaja ili prilagođenim kreditnim uvjetima, te suradnjom s turističkim zajednicama i drugim poljoprivrednim proizvođačima (vinogradari, voćari, stočari) i edukacijom.

ZAKLJUČAK

Na temelju rezultata istraživanja može se zaključiti da bi znatan dio ispitanika godišnji odmor, cijeli ili dio, proveo na agroturističkom gospodarstvu. Za to bi im najprihvatljivije razdoblje bili ljeto i jesen, a najmanje zima. Anketirani preferiraju jednodnevne i/ili vikend izlete. Agroturističku ponudu u Koprivničko-križevačkoj županiji ocjenjuju slabom, a poboljšanje vide u kvalitetnoj promociji i edukaciji ponuđača i potrošača te većem angažmanu županijske i gradske turističke zajednice te njihovoj suradnji sa poljoprivrednim proizvođačima.

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AGRITOURISM DEMAND FEATURES FROM THE ĐURĐEVAC RESIDENTS POINT OF VIEW

ABSTRACT

Tourism is one of the most important „industries“ in Croatian economy. Besides the so called "sea" tourism that is mostly taking place in the few summer months, in recent years there is increasing of foreign visitors and domestic tourists to destinations in continental part of State. Rural tourism, and especially agrotourism attracts an increasing number of visitors and it is often not only adding segment of the tourist offer, but also dominant in the income of family farms. In this way it becomes a driving force of agricultural development.

This paper examines the current and future agritourism demand from the view of Đurđevac city residents living in rural areas. This paper was based on the assumption that the tourism resources are insufficiently evaluated and that the general and agritourism offers are relatively modest. The aim of paper is to describe agrotourism demand of the Đurđevac City inhabitants and their attitudes towards certain elements of rural supply.

For the purposes of paper the survey was conducted on a random sample of 153 respondents on the territory of Đurđevac city. Research has shown that there is significant interest for spending time on agritourism especially in spring and

autumn. The respondents believe that for improving agritourism supply it is necessarily to increase the overall tourist offer and to be better promoted, but also enhance mutual cooperation between county and city tourist offices and interested farmers.

Key words: *agritourism, demand, Koprivnica-Križevci County, Đurđevac city*



AGROTURIZAM NA PODRUČJU ĐURĐEVCA: OGRANIČENJA I MOGUĆNOSTI RAZVITKA

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SAŽETAK

Agroturizam je multifunkcionalna djelatnost ruralnog prostora. On pridonosi boljem korištenju proizvodnih i neproizvodnih resursa područja, potiče razvoj tržišta poljoprivrednih i ostalih proizvoda i usluga te približava urbanu populaciju prirodnom okruženju. Cilj rada je istražiti mogućnosti i ograničenja agroturističke ponude na području Grada Đurđevca. Za potrebe rada provedena je anketa na uzorku od 60 namjerno odabranih poljoprivrednika. Rezultati istraživanja su pokazali da bi se samo 3,3 % ispitanika bavilo agroturizmom. Kao glavnu prepreku za pokretanje agroturizma navode nedostatak financijskih sredstava za potrebna dodatna ulaganja. Nasuprot tome, kao osnovni motiv ulaska u projekt agroturizma ističu mogućnosti boljeg iskorištenja raspoloživih resursa te i prodaje vlastitih poljoprivrednih proizvoda i prerađevina što bi dovelo do većeg dohotka kućanstva. Također, agroturizam bi pridonio revitalizaciji ruralnog prostora Đurđevca i okolnih sela, smanjenju nezaposlenosti, a poljoprivredni proizvodi obiteljskih poljoprivrednih gospodarstava bi skratili hranidbeni lanac te na najbolji način promovirali onaj „sa polja do stola“.

Ključne riječi: agroturizam, poljoprivreda, obiteljska poljoprivredna gospodarstva, Đurđevac

UVOD

Agroturizam se u Europi počeo razvijati koncem 20. stoljeća, a posljednjih dvadesetak godina bilježimo njegov značajan razvitak i u Hrvatskoj. Na razvitak agroturizma znatan je utjecaj sve veće znatiželje i određenog avanturizma stanovnika urbanih sredina, ali i želja poljoprivrednika i drugih stanovnika ruralnih područja da ponudom i prodajom svojih proizvoda, usluga i ugođaja povećaju svoj dohodak. Suvremeni potrošač (turista) želi boraviti u seoskom ambijentu, iskušavati regionalna jela, tražiti svoj unutrašnji duhovni sklad i

izgubljeni integritet te doživjeti duboki kontrast života velegrada i male tradicionalne sredine (Šegro, Tomić 1998).

Posebno je jaka veza turizma sa poljoprivredom i to ne samo gospodarstva koji nudi proizvode i usluge, nego izravno ili neizravno i sa drugim poljoprivrednicima i gospodarstvima u lokalnoj sredini. Agroturizam potiče povećanje poljoprivredne proizvodnje unutar agroturističkih gospodarstava (Brščić, 2006) jer pospješuje prodaju poljoprivrednih proizvoda i prerađevina, promovira ih, ali promiče i specifičnost seoskog stila života, regije, pa i države.

Agroturizam prelazi iz „slučajnosti u stalnosti i profesionalnosti“ te mu je sve više neophodan menadžment za razvitak u uvjetima globaliziranog svjetskog turističkog tržišta. On treba biti prepoznatljiv i konkurentan oblik turizma temeljen na održivom razvoju, tradiciji i očuvanju kulturnog identiteta (Bosnić, 2011).

U agroturizmu postoji jaka, prepoznatljiva interakcija domaćin-gost, pri čemu gost nije samo statistički broj ili ključ od sobe, već on postaje sastavni dio obitelji. Turističke usluge su personalizirane i gost postaje istinski prijatelj članova obiteljskog gospodarstva i njemu je na raspolaganju cjelokupni prostor domaćinstva.

Agroturizam je i više od boravka na poljoprivrednom gospodarstvu jer on kapitalizira ruralnu kulturu kao turističku atrakciju (Franić i Cunj, 2007), revalorizira autohtone vrijednosti receptivnog kraja i doprinosi očuvanju kulturnog identiteta (Krajnović i sur., 2011). Prema Bršić i sur. (2010) agroturizam je jedan od najvažnijih oblika ruralnog turizma sa kompleksnošću ponude proizvoda i usluga ali i očekivanja potrošača/agroturista. Agroturističko gospodarstvo može gostu ponuditi vlastite poljoprivredne proizvode, hranu i piće iz vlastite kuhinje, izlete u prirodu, kamping u dvorištu i slično, a sve sa ciljem zadovoljenja složenih potreba turista te ostvarivanja bolje ekonomske uspješnosti gospodarstva (Čurić, 2010). Tubić i sur. (2011) navode kako 53,4% gospodarstva nudi usluge i smještaja i prehrane, njih 48,9% prodaje poljoprivredne usluge i prerađevine, 38,8% gospodarstva pruža usluge prehrane dok njih 33,3% pruža usluge smještaja. Čak 20,5% gospodarstva prodaje i suvenire, a samo 10,1% gospodarstva nudi usluge samo noćenja. U prosjeku svako agroturističko gospodarstvo nudi 2 usluge.

Zbog svega navedenog, agroturizam je prilika za ruralni prostor, za jedan dio poljoprivrednih proizvođača, ali i prilika povratku prošlosti i prirodi za osobe iz urbanih sredina voljnih doživjeti nešto zaboravljeno i nesvakidašnje.

I grad Đurđevac očekuje da će kroz poticanje razvitka agroturizma bolje iskoristiti raspoložive prirodne i kulturne resurse čime bi se zaustavila ili ublažila demografska devastacija ruralnog ali i gradskog područja. (Agro)turistički prihodi potakli bi i znatnije ulaganje u obiteljsko gospodarstvo ali i u ruralni prostor što bi kvalitetu življenja podiglo na višu razinu.

MATERIJAL I METODE

Za osmišljavanje razvitka agroturizma na istraživanom području bitni su stavovi poljoprivrednika o mogućnosti njihovog uključenja u taj projekt odnosno posebno njihova očekivanja od toga i ograničenja sa kojima se susreću. Zbog toga je za potrebe ovoga rada

provedena anketa tijekom travnja i svibnja 2012. godine slučajnim odabirom poljoprivrednih gospodarstva na području grada Đurđevca. Ukupno je anketirano 60 osoba koje se bave poljoprivrednom proizvodnjom ili imaju registrirano obiteljsko poljoprivredno gospodarstvo. Upitnik je sadržavao 24 pitanja strukturiranog (s višestrukim izborom odgovora) i nestrukturiranog (otvorena pitanja) tipa te *Likertovu* skalu stavova (Psihometrijska skala kojom pokušavamo doznati stupanj slaganja, odnosno neslaganja ispitanika s nekom tvrdnjom.) s 5 stupnjeva. Obrada podataka provedena je pomoću statističkog paketa SPSS 17.0. (*Statistical Package for Social Science*), a rezultati su prikazani tablično i grafički. Pojedine varijable testirane su pomoću χ^2 testa koji je jedan od najčešćih neparametarskih testova. On se temelji na učestalosti pojedinih kategorija rezultata koje se uspoređuju s nekom drugom učestalošću koja bi se očekivala pod određenom *nul*-hipotezom. *Nul*-hipoteza (H_0) predstavlja da za neko svojstvo ima ili nema razlike između uzoraka podvrgnutih testiranju. Uz *nul*-hipotezu postavlja se i radna hipoteza (H_1) koja je oprečna *nul* hipotezi. Testiranjem se prihvaća jedna od postavljenih hipoteza.

REZULTATI I DISKUSIJA

Utemeljenje i pokretanje posla iziskuje određena znanja, vještine i sposobnosti pojedinca ili grupe. Na putu prema uspjehu nekoliko je misli odnosno postulata, a među važnijima su:

- Najbolja investicija je ako radiš vrijedno i savjesno.
- Znanje je jedan od uvjeta uspješnosti te uvijek i stalno uči.
- Sve što radiš radi najbolje što znaš. Onaj tko je učinio najbolje što je mogao, učinio je sve. Tko je učinio manje nego je mogao, nije učinio ništa.

Malo je djelatnosti u ruralnom prostoru, kao što je agroturizam, gdje su ovi postulati tako značajni. Neupućeni pomisle da je za ulazak u agroturizam dovoljno imati višak prostora (kuća, dio kuće, ostali objekti koji se mogu staviti u funkciju turizma), nešto poljoprivredne proizvodnje te malo urediti i doraditi gospodarstvo, ukrasiti ga tradicijskim detaljima te krenuti u posao koji bi se trebao razvijati sam od sebe, bez dodatnih napora (Grgić 2014). I zbog zamki koje nas čekaju potrebno je pronaći odgovor na nekoliko pitanja kao što su:

- Je li bavljenje agroturizmom zaista za mene?
- Na čemu ću temeljiti i razvijati ponudu, odnosno koji su moji potencijali (znanje, iskustvo, nekretnina, poljoprivredna proizvodnja, stari zanat i sl.)?
- Tko bi mi mogli biti potencijalni gosti?
- Koje uvjete moram zadovoljiti, odnosno koje zakone moram proučiti da bi znao koje obveze trebam ispuniti za bavljenje agroturizmom?

Tipično obiteljsko poljoprivredno gospodarstvo u Hrvatskoj je prosječno male proizvodne površine, mješovitog proizvodnog usmjerenja, male tržnosti, prosječno malog broja članova kućanstva nepovoljne dobne i obrazovne strukture. Ovakvi „tip gospodarstva“ nije najbolji potencijal za bavljenje agroturizmom, ali agroturizam mnogima je i jedna od prilika njegovog opstanka.

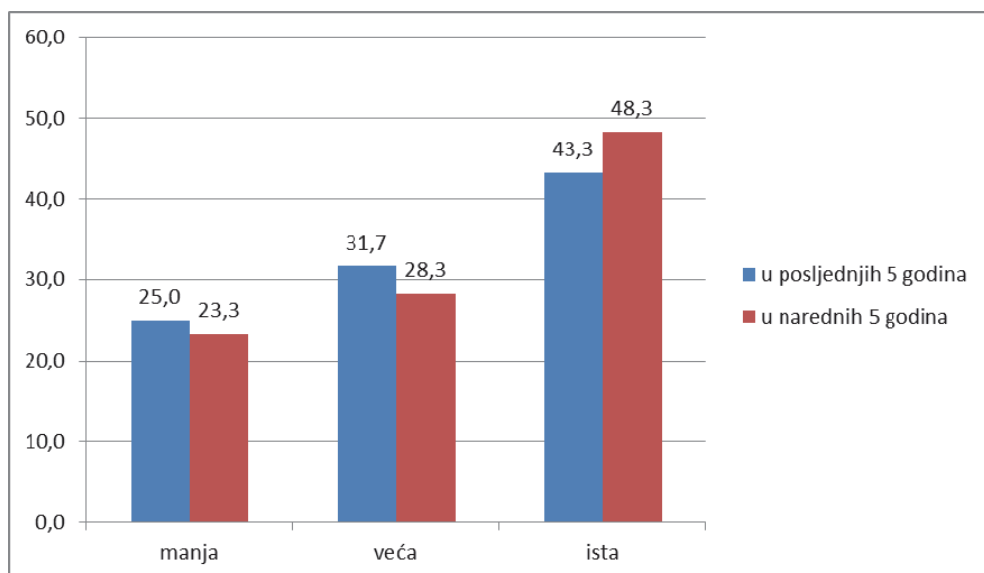
Socio - demografske značajke ispitanika

Najveći dio (58,3%) anketiranih je iz kućanstava koji imaju od 4 do 6 članova, manji dio (36,7%) dolazi iz obitelji do 3 člana te najmanji dio (5%) iz obitelji sa preko 7 članova.

Prosječna dob ispitanika je 42 godine pri čemu ih je više od polovice (56,6%) bilo ispod te dobi. I obrazovna struktura je dosta povoljna te dvije trećine (61,7%) ih ima završenu srednju školu, skoro trećina (26,7%) višu i visoku te najmanje (11,7%) osnovnu ili nezavršenu osnovnu školu.

Iako svi imaju poljoprivrednu proizvodnju različitog obujma, najveći dio ispitanika je u radnom odnosu (43,3%), oko četvrtine ispitanika (23,3%) su poljoprivrednici, a ostali su obrtnici, umirovljenici i ostali.

Na razvitak agroturizma značajan je utjecaj stanja u poljoprivredi odnosno očekivanja ispitanika u narednom razdoblju. Često se iz toga mogu i procijeniti potencijali za agroturizam.



Graf 1 Promjene poljoprivredne proizvodnje na anketiranim gospodarstvima u posljednjih 5 i očekivanja u narednih 5 godina; Izvor: Anketa

Graph 1 Change of agricultural production at inquiryed farms during last 5 years and expectance of further 5 years; Source: Carried out Inquiry

Pokrenuti agroturizma mogu po kapacitetima i proizvodnji i tzv. mali, veliki i srednji proizvođači, te su promjene u poljoprivrednoj proizvodnji dobar, ali ne i istoznačan pokazatelj mogućih promjena u agroturizmu. Nositelji buduće poljoprivredne proizvodnje su trećina današnjih obiteljskih gospodarstava, dočim to ne priječi i ostale da se započmu baviti agroturizmom koji je prilika za sve, ali sa različitim početnim motivima. Do sličnih rezultata za područje Grada Zagreba došao je Grgić 2008. Gospodarstvima koja bilježe

smanjenje poljoprivredne proizvodnje, agroturizam bi mogao biti poticaj povećanja proizvodnje kao i onima koji bilježe stagnaciju. Gospodarstvima koja jačaju i povećavaju poljoprivrednu proizvodnju agroturizam je značajan tržišni kanal za plasman vlastitih proizvoda i prerađevina.

Iako se često ističu velike mogućnosti razvoja te uloga agroturizma u ruralnom prostoru, mnoga istraživanja su pokazala da je mali ineteres poljoprivrednika koji bi ušli u tako zahtjevan, neizvjestan i skup projekt (Grgić 2008).

Tablica 1 Namjera bavljenja agroturizmom u narednih pet godina
Table 1 Intention of including agrotourism within futher 5 years

Odgovori (Answers)	f	%
sigurno ne (surely No)	24	40,0
vjerojatno ne (possibly No)	16	26,7
ne znam (don't know)	15	25,0
vjerojatno da (possibly Yes)	3	5,0
sigurno da (surely Yes)	2	3,3
Ukupno (Total)	60	100,0

Izvor: Isti kao za Graf 1, Source: same as Graph 1.)

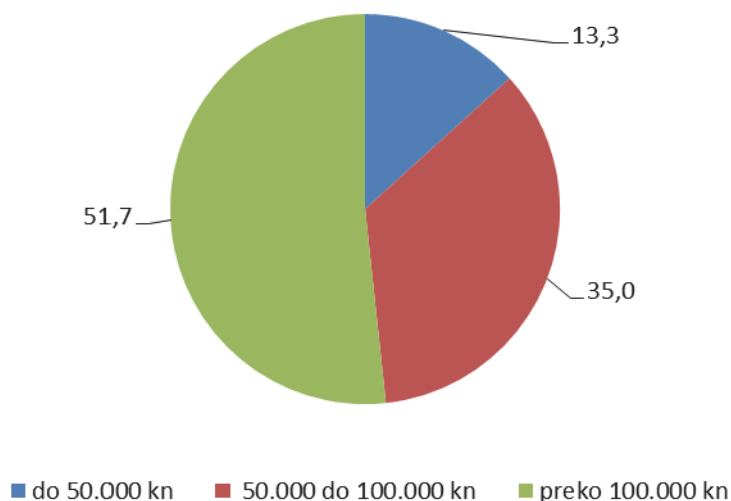
Tako je i ovo istraživanje pokazalo da je samo 3,3% ispitanika sigurno da bi se bavilo agroturizmom te je još njih 5% izjavilo da bi vjerojatno. Ovako relativno mali postotak voljnih za bavljenje agroturizmom možemo pojasniti tradicionalnim nedostatkom poduzetničkog duha kao i time da do danas na području Đurđevca nije registrirano niti jedno agroturističko gospodarstvo. Značajniji iskorak je učinjen u utemeljenju vinske ceste sa ubilježenim i markiranim podrumima na karti te to može biti osnovica za razvitak „pravog“ agroturizma. Ideju vinske ceste podržala je i Turistička zajednica grada Đurđevca što bi učinila i kod nužne potpore za pokretanje agroturizma.

Mlađe osobe su sklonije riziku i lakše prihvaćaju nepoznate stvari te i u ovom istraživanju većina osoba koje bi „sigurno“ i „vjerojatno“ ušle u projekt agroturizma su u dobi od 18 do 30 godina. Motivi su vrlo često subjektive naravi i različiti su od osobe do osobe, ali ipak za većinu ispitanika glavni motiv za pokretanje agroturizma bi bio financijska korist (profit). Oni ispravno promišljaju da takva djelatnosti može i treba angažirati sve članove kućanstva, a manji dio bi sam pokrenuo agroturizam i radio na njemu. Do nedavno je čak i zakonski bilo zabranjeno zapošljavanje osoba izvan obitelji.

Do sličnih nalaza došli su Tubić i sur. (2011) u istraživanju na području Slavonije i Baranje gdje su ispitanici naveli da 89,9% gospodarstava zapošljava samo članove obitelji, a 35,6% zapošljavaju i stalno zaposlene te sezonske radnike.

Agroturizam vrlo često zahtijeva i dodatna ulaganja, najčešće za uređenje prostora za prijem gostiju, pripremu hrane, prodajnog dijela, sanitarija i sl. što su potvrdili i svi anketirani. To je zakon uredio i to Zakon o ugostiteljskoj djelatnosti (NN 80/13, NN 50/12, NN 88/10, NN 43/09, NN 138/06, NN 152/8), Zakon o pružanju usluga u turizmu (NN

88/10, NN 68/07) te Pravilnik o pružanju ugostiteljskih usluga u seljačkom domaćinstvu (NN 118/11, NN 44/11, NN 48/08, NN 05/08). I oni većinom navode potrebe za izgradnjom smještajnih kapaciteta za primanje turista, uređenje sanitarnih čvorova, prostora za pripremanje i posluživanje domaćih specijaliteta.



Graf 2 Neophodna ulaganja na obiteljskim poljoprivrednim gospodarstvima za razvoj agroturizma; Izvor: Isti kao za Graf 1

Graph 2 Necessary investment at Family farms for development of agrotourism; Source: same as Graph 1

Za razliku od maritimnog turizma, koji uglavnom podržavaju i izgradnju novih kapaciteta zbog velikog broja turista s drugačijim potrebama, agroturizam nema takve potrebe. Razvoj agroturizma zagovara održivi razvoj manje agresivan po okolinu te se revitalizaciju već postojećih kapaciteta koji se prenamjenjuje u turistički objekat. Znatno jemanja potreba za izgradnjom novih objekata nego kod „tradicionalnog“ turizma. Više od polovice ispitanika za pokretanje agroturizma trebali bi uložiti više od 100.000 kn, oko trećine od 50.000 do 100.000 kn te manji dio bi trebao do 50.000 kn. Kod ovoga osim samih izvora financiranja problem predstavlja i potrebna dokumentacija te nedovoljna kreditna sposobnost potencijalnih ulagača.

Jedan od velikih problema sa kojima se susreću novi poduzetnici pa tako i oni koji bi pokrenuli projekat agroturizma su nedostatak kvalitetne podrške posebice kod dobivanja kvalitetnih informacija. Rijetkost je da se lokalna samouprava ekipirala da bi bila kvalitetan servis zainteresiranim te su oni orijentirani na svoje bližnje. Tako je i u ovom istraživanju najveći dio ispitanika (61%) odgovorio da bi se prilikom pokretanja agroturizma posavjetovalo s članovima obitelji, a manji dio s osobama s iskustvom u toj djelatnosti, sa stručnjacima, prijateljima, dok najmanji dio smatra da bi to ipak trebala biti odluka pojedinca.

Agroturizam izravno pridonosi razvoju ruralnog područja te je nužna očekivana podrška lokalne zajednice i samouprave te turističkih, savjetodavnih i financijskih institucija. Na

pitanje „Tko bi ima najviše trebao pomoći prilikom pokretanja agroturizma“, većina ispitanika (63,3%) najviše vjeruje i očekuje od lokalne samouprave kao i od potencijalne agencije koje se bave agroturizmom. Polovica ih ima povjerenja u banke i turističke zajednice te samo njih 8% ne očekuje nikakvu pomoć. Ispitanici su realni u očekivanjima te najviše ih očekuje pomoć u adiministrativnom dijelu, manje u obliku financijske pomoći (subvencije), zatim oglašavanja (promocije) te edukacije. Povećanjem educiranosti pružatelja usluga značajano bi se utjecalo na razinu „neznanja“ kada su u pitanju administracija i načini oglašavanja.

Iako su svjesni da agroturizam predstavlja znatno veću angažiranost nego samo poljoprivredna proizvodnja, očekivanja su velika, različita i realna.

Tablica 2 Agroturizam na gospodarstvu bi (ne znam=1, uopće ne=2; malo=3, dosta=4, jako=5):

Table 2 Wishing agrotourism at farm aiming (don't know=1, surely No=2, slightly=3, fairly=4, strongly=5)

	N	Min	Max	$\bar{X}$	Sd
smanjio rizik poslovanja gospodarstva (diminishing business risk)	60	1	5	2,78	1,29
poboljšao prodaju poljoprivrednih proizvoda (improving agricultural products selling)	60	1	5	3,82	1,359
pridonio boljem korištenju radne snage (increasing of labour using)	60	1	5	3,42	1,394
smanjio troškove poslovanja (decreasing business expenses)	60	1	5	2,73	1,233
povećao dohodak i blagostanje (income and prosperity increasing)	60	1	5	3,78	1,342

Izvor: Isti kao za Graf 1
Sorce: same as Graph 1

Najveći dio (72%) ispitanika ulogu i doprinos agroturizma očekuje u prodaji poljoprivrednih proizvoda. Boljom prodajom svojih proizvoda ostvariti će i veće prihode na gospodarstvu te povećati ukupno „blagostanje“. Korist od utjecaja agroturizma na smanjenje troškova poslovanja njihovog gospodarstva očekuje četvrtina ispitanika te značajan dio ih smatra da bi na taj način bolje koristili raspoloživu radnu snagu. Osim ekonomskih koristi, agroturizam doprinosi poboljšanju društvenih odnosa i suradnje među sumještanima jer ako ima „ima posla“ ljudi su više upućeni jedni na druge.

ZAKLJUČAK

Istraživanje o mogućnostima razvitka agroturizma na području grada Đurđevca pokazalo je da ispitanici shvaćaju da bi njegov razvitak pozitivno utjecao na prodaju poljoprivrednih proizvoda, njihovu promociju, ali i promociju specifičnog seoskog stila života, regije, pa i države. Ipak, mali broj poljoprivrednika (3,3%) zainteresiran je za bavljenje agroturizmom, a kao glavni motiv za bavljenje agroturizmom navode zaradu pri čemu je najveća prepreka

za pokretanje agroturizma neophodnost većih ulaganja. Nedostatak kvalitetnih informacija i strah od nepoznatog prisutni su kod velikog dijela ispitanika (63%) te bi kod pokretanja agroturizma potražili pomoć lokalne samouprave.

Da bi projekt agroturizma uspio posjetitelju treba omogućiti vizualni doživljaj (životinje, ptice, poljoprivredna gospodarstva, seosku kulturu, nošnje i manifestacije), sudjelovanje (poslovi na gospodarstvu, jahanje, priprema tradicionalnih jela, narodne igre i sl.) te „razlog“ dodatne potrošnje novca (kupnja rukotvorina, narodnih nošnji, proizvoda s gospodarstva, suvenira i sl.)

Vlasnici agroturističkih gospodarstava, turistički promotori i institucionalni okvir su preduvjet uspjeha razvoja agroturizma temeljenog na postojećim resursima i atrakcijama.

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AGRITOURISM IN ĐURĐEVAC CITY AREA: DEVELOPMENT CONSTRAINTS AND OPPORTUNITIES

ABSTRACT

Agritourism is a multifunctional activity of rural areas. It contributes to a better use of production and non-production resources in area; it encourages the development of the agricultural and other products markets and services and it is also making the urban population closer to natural environment. The aim of paper is to explore the possibilities and limitations of agritourism supply in Đurđevac city. For the paper purposes the survey was conducted on a sample of 60 intentionally selected farmers. The results showed that only 3.3% of respondents are engaged in agritourism. As a major obstacle for starting with agritourism respondents emphasized the lack of funding for additional investment. In contrast, as the main motive for entering into the agritourism project they emphasized the possibilities of better utilization of available resources and the sale of own agricultural products and products which would lead to higher household income. Also, agro-tourism would contribute to the revitalization of Đurđevac city rural areas and surrounding villages, through reducing unemployment; and agricultural products from family farms would make the food chain shorter, and that would be the best way to promote the "from farm to table" consumption.

Key words: agrotourism, agriculture, family farms, Đurđevac city



CONSUMPTION OF PUMPKIN OIL IN CROATIA AND SLOVENIA, CONSUMERS' ATTITUDES

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ABSTRACT

Research of consumption pumpkin oil was conducted with 80 randomly taken consumers from Croatia and 80 consumers from Slovenia. The questionnaire contained 19 questions from which demographics of the participants, their frequency of pumpkin oil consumption, as well as the reasons of consumption, and the specific evaluation of user satisfaction with characteristics of pumpkin oil was obtained. The survey found that 42% of Croatian and 62% of Slovenian respondents often consumed pumpkin oil, while 31% of Croatian and 20% of Slovenian respondents consumed occasionally, and 27% of Croatian and 18% of Slovenian respondents rarely or never consumed pumpkin oil. The importance of price when buying pumpkin oil also plays a role in consumption. To the question how important is the price when they are buying pumpkin oil, most of the respondents, responded that it is important, 53% in Croatia and 56% in Slovenia, but one part of consumers are willing to pay higher prices for quality oil, due to his nutritive and health values.

Key words: pumpkin oil, oil consumption, survey questionnaire

INTRODUCTION

Largest European producer and exporter of oil pumpkin seeds and pumpkin oil is Austria, with an annual processing of pumpkin oil of approx. 100.000 tons. Beside Austria growing oil pumpkins is also traditional in Slovenia and Croatia (Međimurje, upper Podravina and Slavonia). Mostly grown pumpkin is hull-less pumpkin, *Cucurbita pepo* var. *oleifera*, for the production of pumpkin oil. Its seeds haven't got a strong shell (Lešić et al., 2004). Regular pumpkin seeds contains 5,0-7,9% water, 33,1% oil, 29,5% proteins, 22,8% cellulose and 3,5% ash. Hull-less pumpkin seeds contains 5,7-7,4% water, 51,0% oil, 32,5% proteins, 4,4% cellulose (Štrucelj, 1981). Growing oil pumpkin (*Cucurbita pepo* L.)

can be a highly profitable business. If achieved yields and seeds quality are according to market requirements and are accompanied with assured placement on domestic and foreign markets. The seeds are used for different purposes, mostly for the processing in the oil, then they can be placed into the form of a reprocessed and polished seeds, which beside nutritional has also medicinal properties (Martinov et al., 2011). Recent production of oil pumpkin is completely mechanized mostly with conventional equipment, while harvesting requires special and expensive machines. (Ploj, 1987; Wagner, 1998; Sito, 1999). Processing harvested seed is also solved, where they use conventional machinery and equipment for seed production, as well as special machines for washing and polishing (Bojić et al., 2007; Sito 1999). It is estimated that in Croatia oil pumpkin is grown at 4.000-5.000 hectares, with only about 50% of the production is financially supported by Ministry of agriculture Republic of Croatia. According to statistics in Slovenia the oil pumpkin is grown in 2013. cca. 3.750 hectares. The most of the smaller producers, if it is required, process dried and processed seeds and sell the oil directly on its own farms, in order to achieve maximum profit (Statistični urad Republike Slovenije). Pumpkin seeds are rich in vitamin E, and vitamins C, B₁, B₂, niacin and provitamin A are still present. Additionally in the seeds there are also sterols and colour holders (chlorophyll, carotene, etc.). Seed also contains minerals and element like boron, copper, manganese, zinc, cobalt, nickel, aluminium, molybdenum, silicon and gold (Štrucelj, 1980). From non glyceride substances, which contain unrefined oil, the most important are vitamins, sterols, phosphatides and minerals. There are also glycosides, waxes, fragrances and taste substances (aldehydes, ketones, etc.), and various hydrocarbons (Štrucelj, 1984). Pumpkin oil is known as oil with high stability, which is much higher than it would be expected based on the fatty acid composition and the presence of chlorophyll and the amount of tocopherol (Vogel, 1978). After the harvest in the field remains about 50-60 t ha⁻¹ of pulp which is usually ploughed as organic fertilizer. However, the pulp can be rationally used to produce high-quality food for people, because it contains a lot of pectin, which is necessary for produce various jams, compotes, fruit juices, bread and baby food. Analyzing pumpkin press-cake, after pressing hull-less pumpkin seeds, it was found that it contains 6-11% oil, 57-60% protein and water content of 4-6% (Štrucelj, 1984). The aim of this paper is to analyze and compare the production and consumption of pumpkin oil in Croatia and Slovenia through the survey conducted with 80 randomly taken consumers in each country Croatia and Slovenia.

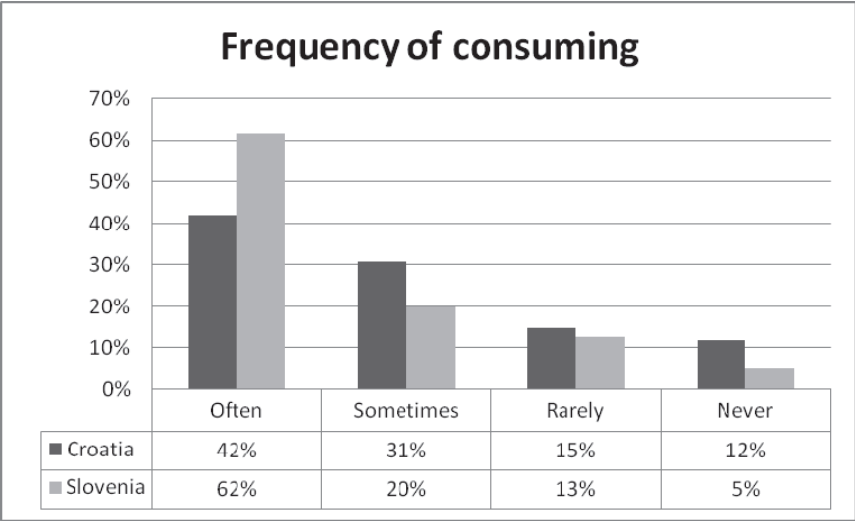
MATERIAL AND METHODS

The questionnaire contained 19 questions from which demographics of the participants, their frequency of pumpkin oil consumption, as well as the reasons of consummation, and the specific evaluation of user satisfaction with characteristics of pumpkin oil was obtained. The collected data were analyzed by univariate statistical methods.

RESULTS AND DISCUSSION

The research was conducted in order to adapt the production of pumpkin oil consumer attitudes. A similar study was done on the cultivation and consumption of potatoes (Sito et al., 2014), and on dried apples fruits (Sito et al., 2013). Among Croatian participants, 41%

of them were male, while 59% were female. In Slovenia, ratio was almost the same: 45% male and 55% female. By age there was a small difference between the Slovenes and Croats. Between 18 and 35 years was 56% Slovenian and 53% Croatian respondents, while other respondents were elderly. In Slovenia, 57% of consumers have higher education, 39% secondary education and only 4% of them has completed only primary school. When Croatian respondents 49% of them have higher education, 45% had secondary school education, and 6% have only completed primary school. By place of residence, 40% of Slovenian consumers living in urban areas and 60% live in rural areas, while 57% of Croatian consumers living in urban areas, and 43% in the countryside. The survey found that 42% of Croatian and 62% of Slovenian respondents often consumed pumpkin oil, while 31% of Croatian and 20% of Slovenian respondents consumed occasionally, and 27% of Croatian and 18% of Slovenian respondents rarely or never consumed pumpkin oil. During the research it was found that many or most respondents have continued consumption of pumpkin oil after they taste it once. (Graph 1).

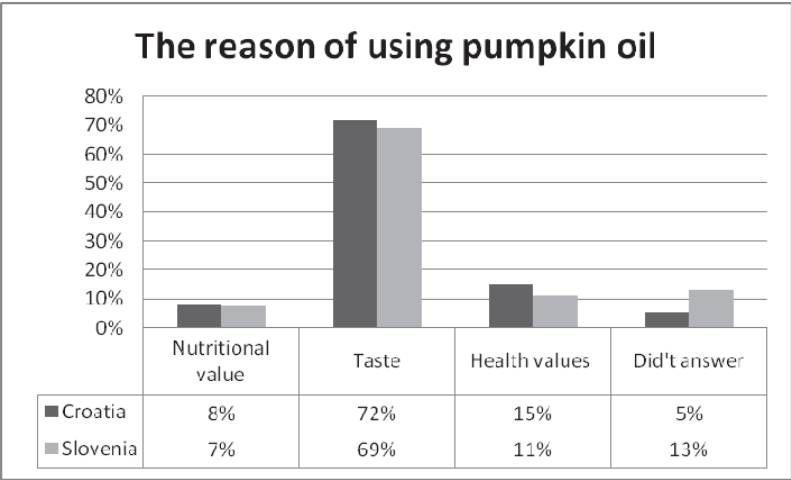


Graph 1 The frequency of pumpkin oil consumption

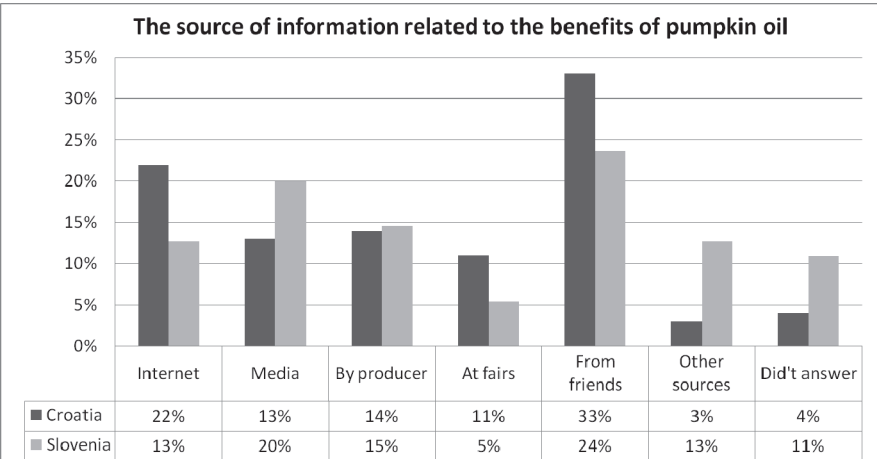
To the question that is the reason why they like pumpkin oil, respondents were offered answers: nutritional value, consuming pleasure, health values and / or other reasons. The answer "pleasure in consuming" chose 72% of Croatian and 69% of Slovenian respondents. This is not surprising, because what makes pumpkin oil so special is its nutty flavor and aroma of fresh bread, which not only enrich soups and salads, but also cheeses and desserts. However, those who had once accepted pumpkin oil, salads and cold dishes are unimaginable without its characteristic odor and taste (Graph 2).

The questionnaire contained a question about the origin of the information they have on pumpkin oil (Graph 3). The highest percentage of both Croatian (33% of them) and Slovenian respondents (24%) received information from friends, while the next ranked

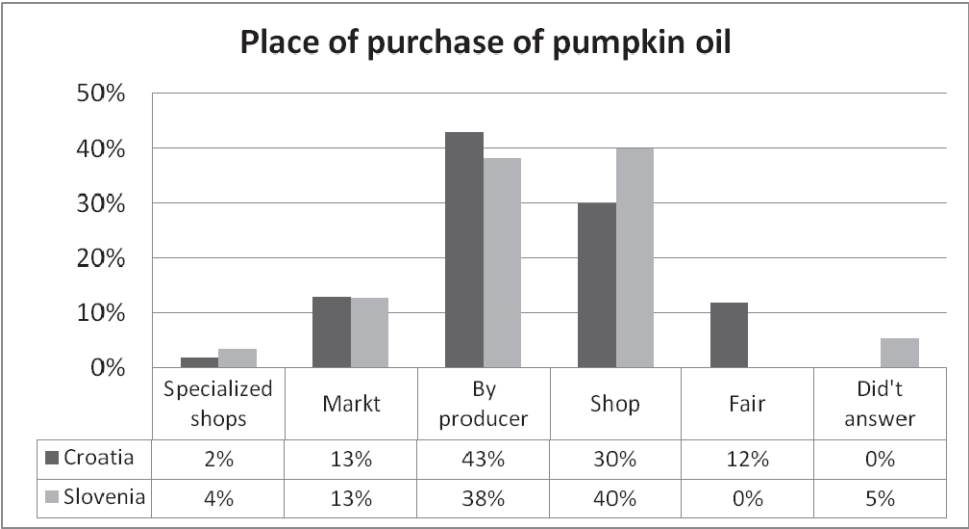
source of information was Internet, as well as newspapers and other media. When inquiry participants were asked to rate the degree of confidence of the information on scale of 1 to 5 (where 1 = not at all trust, and 5 = strongly trust), the obtained mean rating of the Croats was 3.89, while the Slovenes was 3.63 - which would mean that respondents have quite trust in the information they receive about the pumpkin oil. The largest number of Croatian respondents, even 43%, buy pumpkin oil directly from the manufacturer, while Slovenian respondents, 40% of them mostly buy oil in stores (Graph 4). These data are not surprising because consumers often have a sense of loyalty to the manufacturers whose products they like and direct sales is the best way to create a personal and positive relationship with the consumer.



Graph 2 The reasons of pumpkin oil using

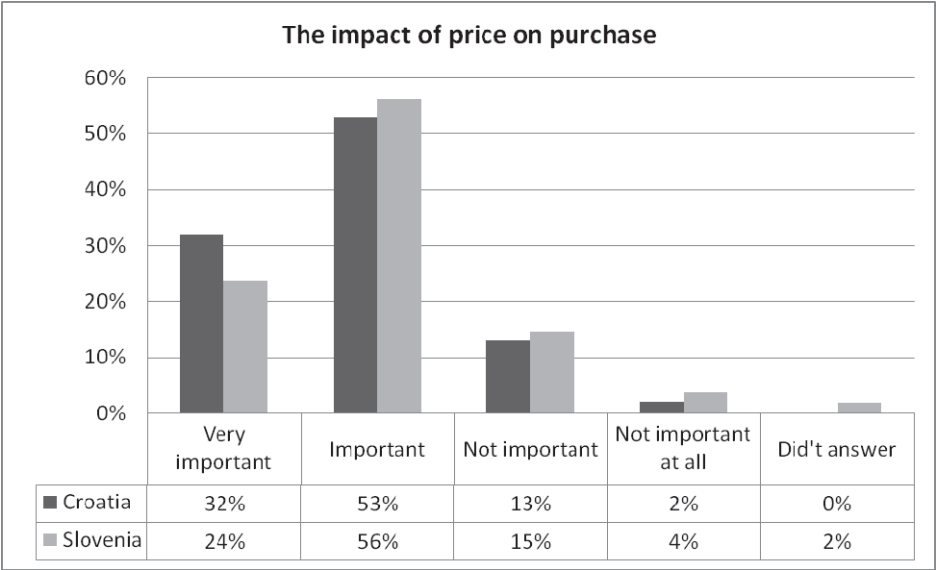


Graph 3 Results on the source of information related to the benefits of pumpkin oil



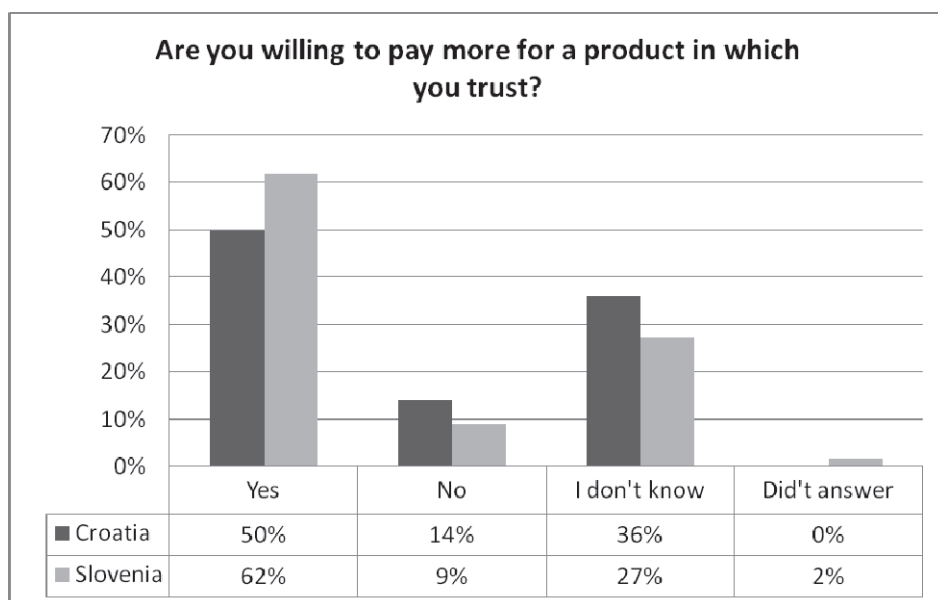
Graph 4 The results of the place of purchase of pumpkin oil

The importance of price when buying pumpkin oil also plays a role in consumption. To the question how important is the price when they are buying pumpkin oil, most of the respondents, responded that it is important, 53% in Croatia and 56% in Slovenia, or even very important, 32% in Croatia and 24% in Slovenia (Graph 5).



Graph 5 The influence of price on the purchase of pumpkin oil

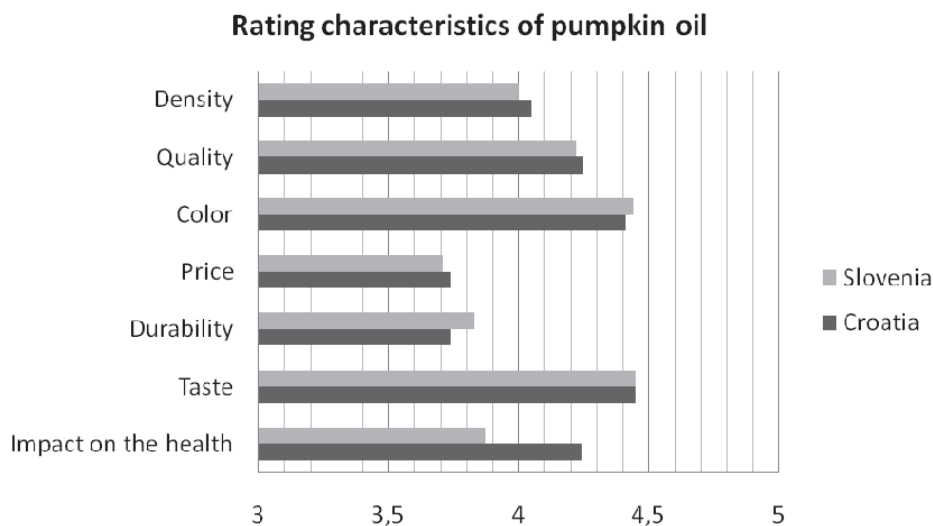
Also, the majority of Croatian and Slovenian consumers stated that they preferred the oil from organic versus conventionally grown pumpkins. Satisfaction with offer of pumpkin oil on the market (grade 1-5; 1 = completely dissatisfied / a, 5 = completely satisfied / a), Croatian and Slovenian respondents evaluated with medium score of 3.75, and approximately 25% of the respondents have a favorite producers whose oil they targeted buying (which can be result of high satisfaction with the quality, and to have such consumers is the goal of every manufacturer). To the question which oil they prefer, warm (conventional) or cold-pressed, 85% of respondents preferred cold pressed. Additionally as a reason, they emphasized that cold pressing retains more nutrients and beneficial ingredients that are lost by conventional molding. And they are right in terms of quality of pumpkin oil. The highest quality has a cold-pressed pumpkin oil which is ranked similar like as "virgin" olive oil in the production terms. The oil is very dark green color and densely, and has a specific taste like pumpkin seeds. The process of obtaining oil by this process is quite slow, so the price of such products is high. Heating oil can get a better flavor, but lose the healthy ingredients. If on the bottle isn't statement "cold pressed" then it's probably obtained using heat. This procedure pumpkin oil can be produced much faster, but lose the healthy ingredients and are usually more mixed with sunflower oil. The taste can vary, but often it can be felt the taste of roasted seeds or sunflower oil. As mentioned above, due to the manufacturing process, pumpkin oil "holds" a high price. So we tried to find out through a survey whether the consumers are aware of the expensive and slow process, and how many are willing to pay for the resulting quality. Up to 50% of Croatian and 62% of Slovenian respondents would pay more for pumpkin oil, in average, 20 - 25% higher price than the current one (Graph 6).



Graph 6 The results of respondents' satisfaction with price of pumpkin oil on the market

This data tells us that the majority of consumers believe, that for the product and his quality which they receive by buying pumpkin oil, producers do not ask too high price, and that they are willing to pay more for a quality product.

During the evaluating the characteristics of pumpkin oil, from the consumers was require to evaluate them on the scale from 1 to 5 (in this case 1 = the lowest level for characteristics, and 5 = maximum, eg. in the characteristics of durability 1 = short term, and 5 = long term). Respondents were asked to evaluate the following characteristics of pumpkin oil: health, taste, durability, price, color, quality and density. Croatian respondents described them on the following manner; medium score for health was 4.24; for a taste 4.45; for durability 3.74; for the price 3.74; for the color 4.41; for quality 4.25; and for the density medium score of 4.05. Slovenian respondents rated similar to them; medium score for health was 3.87; for a taste 4.45; for durability 3.83; for the price 3.71; for the color 4.44; for the quality 4.22; and for the density medium score of 4 (Graph 7.). The lowest score achieved characteristics were price and durability. Durability is a problem for producers, but also consumers. The warm (conventional) pressed pumpkin oil are valid up to 12, and cold pressed only up to 6 months! Therefore most of small oil mill works on the principle of order - to ensure as fresher product to his customers, and that doesn't produce supplies of product that can't be sold. Among the highest marks is the one for the health of pumpkin oil.



Graph 7 Results of the opinion of consumers about the characteristics of pumpkin oil

CONCLUSIONS

Based on this study can be bring the following conclusions:

- The consumption of pumpkin oil in human nutrition is quite present as confirmed by the conducted survey in Croatia and Slovenia. During the research it was found that

many or most respondents have continued consumption of pumpkin oil after they taste it once.

- The most of consumers enjoy consuming pumpkin oil. This is not surprising, because what makes pumpkin oil so special is its nutty flavor and aroma of fresh bread, which not only enrich soups and salads, but also cheeses and desserts.
- Consumers often have a sense of loyalty to the manufacturers whose products they like and direct sales is the best way to create a personal and positive relationship with the consumer.
- 85% of respondents preferred cold pressed pumpkin oil. As a reason, they emphasized that cold pressing retains more nutrients and beneficial ingredients that are lost by conventional molding.
- Due to the manufacturing process, pumpkin oil "holds" a high price. Although research has proven that the market price significantly affects the consumption of pumpkin oil, both in Croatia and Slovenia, consumers are willing to pay higher prices for quality oil, due to his health values.

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OGLJIČNI ODTIS VINOGRADNIŠKE PRIDELAVE

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IZVLEČEK

Določen je ogljični odtis mehanizirane vinogradniške pridelave v Sloveniji. Opravljena je analiza ogljičnega odtisa v primeru, konvencionalne, integrirane in ekološke vinogradniške pridelave za tri velikosti kmetij. Pri vseh mehaniziranih delovnih operacijah v vinogradništvu se uporablja energija mineralnega dizelskega goriva za pogon traktorjev z agregatiranimi priključnimi stroji oziroma v primeru strojne trgatve grozdja s samovoznimi stroji - kombajni za grozdje. Za analizo ogljičnega odtisa so vzete emisije CO₂ iz porabljenega mineralnega dizelskega goriva za pogon mehanizacije (direktna energija, ki se porabi v procesu vinogradniške pridelave). Poleg emisije CO₂ iz mineralnega dizelskega goriva uporabljenega v vinogradniški pridelavi so zajete tudi emisije toplogrednih plinov, ki nastanejo zaradi uporabe organskih in mineralnih gnojil v pridelavi in preračunane na ekvivalent CO₂. V primeru konvencionalne pridelave je predvidena uporaba mineralnih gnojil, pri integrirani kombinaciji mineralnega in organskega gnojila, pri ekološki pridelavi pa samo organskega gnojila. Seštevek emisij CO₂, ki nastanejo zaradi uporabe mineralnega dizelskega goriva in ekvivalentnih emisij CO₂ iz gnojil uporabljenih v procesu pridelave, da končno emisijo CO_{2ekv}/t pridelka – grozdja v vinogradniški pridelavi. Ugotovljeno je, da so emisije CO_{2ekv}/t pridelka – grozdja, najnižje pri integrirani, višje pri konvencionalni ter najvišje pri ekološki pridelavi.

Ključne besede: ogljični odtis vinogradniške pridelave, direktna poraba energije, emisije iz mineralnega dizelskega goriva, emisije iz gnojil, emisije CO_{2ekv}/t pridelka – grozdja, emisije CO₂ v konvencionalni, integrirani in ekološki vinogradniški pridelavi

UVOD

Sodoben način pridelave hrane povzroča velike emisije toplogrednih plinov ter odpadnih oziroma stranskih produktov. Najpomembnejši toplogredni plini so ogljikov dioksid, metan in dušikovi oksidi. Ogljikov dioksid se v kmetijstvu sprošča zaradi rabe fosilnih goriv za pogon kmetijskih strojev in druge namene (proizvodnji mineralnih gnojil, različnih procesih, predelavi kmetijskih pridelkov, skladiščenju, hlajenju itn.), del pa zaradi izgub organske mase pri neustrezni rabi in obdelavi tal. Pri zgorevanju mineralnega dizelskega goriva pri opravljanju različnih mehaniziranih delovnih operacij v vinogradništvu, s traktorji s priključnimi stroji ali samovoznimi stroji nastajajo emisije.

PREGLED LITERATURE

Uporaba energije (angl. kratica EU – Energy Use) je definirana, kot neto energija uporabljena za proizvodnjo kmetijskega pridelka dokler ni prodan in zapusti kmetijo oziroma je uporabljen, kot krma v živinoreji (Dalgaard in sodelavci 2001). Uporaba energije se lahko razčleni na direktno in indirektno energijo. Direktna energija (EU_{direktna}) predstavlja vnos energije v samo kmetijsko proizvodnjo. Ko se omenjeni vnos energije lahko direktno pretvori v energetske enote (porabljeno mineralno dizelsko gorivo, maziva, energija utekočinjenega naftnega plina ali zemeljskega plina za dosuševanje, električna energija za naknadno procesiranje pridelka itn.). Indirektna energija ($EU_{\text{indirektna}}$) je energija, ki je porabljena v proizvodnji vnosov uporabljenih v proizvodnji kmetijskega pridelka, ti vnosi pa ne morejo biti direktno pretvorjeni v energetske enote (stroji, gnojila, fito farmacevtska sredstva itn.). Celotna energija za pridelavo kmetijskega pridelka se (Dalgaard in sodelavci 2001) lahko predstavi s pomočjo enačbe (1).

$$EU_{\text{pridelka}} = EU_{\text{direktna}} + EU_{\text{indirektna}}$$

$$EU_{\text{pridelka}} = (EU_{\text{dizel}} + EU_{\text{ostala}}) + EU_{\text{indirektna}} \quad (1)$$

V primeru mehanizirane vinogradniške pridelave se uporablja za pogon traktorjev agregatiranih s priključnimi stroji in samovoznih kmetijskih strojev mineralno dizelsko gorivo, kar pomeni da je EU_{direktna} (1) posledica zgorevanja omenjenega goriva. Po teoriji verižnih reakcij vstopne snovi v končne produkte ne prehajajo neposredno temveč prek zaporedja vmesnih produktov. Pri popolnem zgorevanju goriv, ki vsebujejo ogljikovodike, teoretično nastajata samo ogljikov dioksid (CO_2) in vodna para (H_2O). Poleg tega vsebujejo produkti zgorevanja tudi odvečni kisik (O_2) in dušik (N_2). Ker pa zgorevanje ni nikoli popolno, je v izpušnih plinih še veliko drugih produktov (Gruden 2011). Za celotne emisije CO_2 in drugih toplogrednih plinov, ki so nastali v procesu zgorevanja motorjev z notranjim zgorevanjem se da določiti ekvivalentna količina CO_2 , ki je potrebna da povzroči efekt toplogrednega plina. Ta količina je izražena z enoto kilogram ogljikovega dioksida - ekvivalent ($\text{kgCO}_{2\text{ekv}}$). Emisije mineralnega dizelskega goriva znašajo 3,18 $\text{kg CO}_{2\text{ekv}}/\text{kg}$ goriva oziroma 2,67 $\text{kg CO}_{2\text{ekv}}/\text{l}$ goriva (Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting, 2012).

Različni avtorji poročajo, da je za porabo mineralnega dizelskega goriva za različne kmetijske operacije potrebno vzeti povprečne vrednosti, ker izmerjene vrednosti za porabo

goriva, ki jih podajajo v l/ha ali kg/ha lahko zelo variirajo (Handler 2011; Dalgaard 2001; Jejčič in sodel. 2014).

MATERIAL IN METODA DELA

V raziskavi so določeni ogljični odtisi za vinogradniško pridelavo za tri velikosti kmetije (mala, srednja in velika) in tri vrsti pridelave (konvencionalna, integrirana in ekološka) v Sloveniji. Za določanje ogljičnega odtisa v vinogradniški pridelavi (grozdje za vino) je opravljena analiza konvencionalne, integrirane in ekološke pridelave glede porabe energije (v analizah se izhaja iz že vzpostavljenih vinogradov v polni rodni dobi). Za določanje porabe energije so narejeni modelni izračuni s podatki iz domačih in tujih znanstveno strokovnih baz, podatkov za porabo energije in emisije toplogrednih plinov v kmetijstvu ter z merjenjem porabe energije na vzorčnih kmetijah, zaradi dopolnitev podatkovne baze v primerih, kjer obstaja premajhna količina podatkov ali pa so podatki neuporabni za naše razmere zaradi specifičnosti vinogradniške pridelave oziroma so nezanesljivi. Pri energetske analizi so razčlenjeni vnosi energije (direktna energija), ki je kompletno porabljena v obdobju pridelave grozdja. Vnosi energije skozi daljše časovno obdobje oziroma indirektna energija (za izdelavo traktorjev, priključnih strojev, opreme itn. ter energija za proizvodnjo mineralnih gnojil in zaščitnih sredstev) pa ni upoštevana v tem prispevku. Za ugotavljanje porabe energije v vinogradniški pridelavi smo izbrali tri vzorčne kmetije. Poraba energije v mehanizirani vinogradniški pridelavi je definirana, kot energija fosilnega goriva (mineralno dizelsko gorivo), ki se uporabi pri izvajanju različnih mehaniziranih delovnih operacij. Celotna energija, ki se porabi za pridelavo grozdja na površini enega hektarja, je ugotovljena s seštevanjem energetske porabe vsakega posameznega energetskega vnosa (2).

$$E_p = E_{ot} + E_g + E_n + E_v + E_p + E_t \quad (2)$$

E_p = Celotna energija porabljena v pridelavi grozdja (J)

E_{ot} = energija za osnovno in dopolnilno obdelavo tal

E_g = energija za gnojenje

E_n = energija za nego

E_v = energija za varstvo

E_p = energija za pobiranje pridelka (strojno)

E_t = energija za interni transport pridelka

Vsi načini pridelave imajo določene delovne operacije, ki so podobne ali enake, kot so npr. gnojenje tal, nega nasadov, varstvo rastlin in pobiranje pridelka ter interni transport. Pri vseh omenjenih delovnih operacijah se uporablja energija iz mineralnega dizelskega goriva (pogon traktorjev z agregatiranimi priključnimi stroji oziroma v primeru strojne trgatve grozdja s samovoznimi stroji – kombajni za grozdje). Pri ostalih delovnih operacijah pa so večje razlike med načini pridelave. Npr. osnovna obdelava tal se opravi pri formiranju trajnega nasada, dopolnilna obdelava tal (predvidena v konvencionalni pridelavi) pa v že formiranem trajnem nasadu. V konvencionalni pridelavi v vinogradništvu se poleg varstva nasada s fitofarmaceutskimi sredstvi, uporablja še fitofarmacevtska sredstva oziroma

herbicide za zatiranje plevelov in trave v vrstah v nasadih. V integrirani pridelavi se uporabljajo za varstvo nasadov samo določena fitofarmacevtska sredstva, za zatiranje plevelov v vrsti pa se uporabljajo mehanske metode oziroma mulčenje. Pri ekološki pridelavi se uporabljajo samo fitofarmacevtska sredstva, ki so dovoljena v tovrstni pridelavi, za vzdrževanje prostora v vrsti pa samo mehanske metode za zatiranje plevelov ali mulčenje. V primeru dopolnilne obdelave tal (konvencionalna pridelava) je predvidena medvrstna obdelava tal z branjem s krožno brano, oziroma možnost uporabe rotacijskih strojev za obdelavo tal (strojev, ki so gnani prek priključne gredi traktorja) in to vrtavkaste brane ali prekopalnika - freze. Pri rotacijskih strojih gnanih prek priključne gredi zadostuje za dopolnilno obdelavo tal en prehod prek obdelovalne površine za razliko od vlečenih izvedb traktorskih priključnih strojev npr. krožne brane, kjer sta potrebna dva ali celo trije prehodi. Za gnojenje je v primeru konvencionalne pridelave predvideno gnojenje s trosilnikom mineralnih gnojil. V primeru ekološke pridelave je predvideno gnojenje s trosilnikom hlevskega gnoja, v integrirani pa uporaba trosilnika mineralnega gnoja in trosilnika hlevskega gnoja. Za varstvo rastlin v konvencionalni in integrirani pridelavi je predvidena uporaba vinogradniških pršilnikov (z aksialno ali radialno izvedbo puhalnikov) za nanašanje fitofarmacevtskih sredstev. V integrirani pridelavi se uporabljajo fitofarmacevtska sredstva v manjših količinah, kar pomeni tudi manjše število prehodov traktorskih agregatov s pršilniki. Za nego je predvideno medvrstno vzdrževanje zatavljenih površin z mulčerji (kladivarji ali elisni), ki so namenjeni za mulčenje trave ter pri zimskem ali spomladanskem obrezovanju drobljenju ostankov obrezovanja. Pri ekološkem načinu pridelave je predvideno mehansko zatiranje plevelov v vrstah trajnih nasadov s traktorskimi priključnimi stroji. Spravilo pridelka je ročno (prevladuje za spravilo grozdja v manjših vinogradih ter v večjih vinogradih za kakovostna in vrhunska vina) ali strojno s kombajni za grozdje (v večjih in velikih vinogradih, ki pridelujejo grozdje za namizna vina). Za interni transport so predvidene posebne izvedbe prikolic za boks palete in standardne traktorske prikolice.

Poraba energije je ugotavljana pri opravljanju delovnih operacij s traktorskimi priključnimi stroji (agregat traktor + priključni stroj), ki so namenjeni za osnovno in dopolnilno obdelavo tal, gnojenje, nego, varstvo itn. Merjena je porabljen količina mineralnega dizelskega goriva, ki se porabi pri delu traktorjev z različnimi priključnimi stroji oziroma delu samovoznih strojev (npr. kombajni za pobiranje grozdja). Poleg tega je zajeta poraba energije za interni transport pridelkov na sami kmetiji - transport s traktorji. Pri ugotavljanju porabe energije v mehanizirani vinogradniški pridelavi je ugotovljeno, da poraba goriva za enake delovne operacije lahko zelo variira, ker je odvisna od pedofizikalnih lastnosti tal, načina obdelave, tehnike uporabe traktorskega agregata (traktor + priključni stroj), stanja stroja, usklajenosti moči traktorja glede velikosti priključnega stroja, števila prehodov traktorskih agregatov za posamezno delovno operacijo itn. Modelni izračuni so narejeni na osnovi povprečnih porab goriva za posamezne delovne operacije.

Za gnojenje je predvidena uporaba mineralnega gnojila pri konvencionalni pridelavi, v integrirani je predvidena uporaba mineralnega gnojila in organskega gnoja (v razmerju 80 % mineralno in 20 % organsko gnojilo). Pri ekološki pridelavi pa je predvidena uporaba organskega gnoja (hlevski gnoj). Poraba gnojil je opredeljena na osnovi tehnoloških normativov. Količina gnojil je izražena v obliki čistih hranil (dušik, fosfor, kalij), količine gnojil pa so preračunane na količine pridelka. Za varstvo rastlin so predvidena fitofarma-

cevtška sredstva, ki se uporabljajo pri konvencionalni in integrirani pridelavi (v prispevku je vrednotena samo direktna energija oziroma energija za pogon strojev za nanašanje fitofarmacevtskih sredstev). Za ekološko pridelavo pa so predvidena samo zaščitna sredstva, ki so dovoljena v ekološki pridelavi (ni uporabe konvencionalnih fitofarmacevtskih sredstev, dovoljena pa je uporaba bakrovih in nekaterih drugih preparatov), zamenjavo za herbicide pa predstavlja uporaba mehanskih metod za zatiranje plevelov (npr. traktorski priključni stroj, ki mehansko eliminira plevela v vrstah vinograda, med vrstami pa se uporablja mulčenje). Pri izdelavi modela je predpostavljeno minimalno število nanašanja dovoljenih fitofarmacevtskih sredstev - bakrovi in nekateri drugi dovoljeni preparati. Za količine pridelkov so uporabljeni podatki KGZS in SURS (povprečje zadnjih deset let).

REZULTATI RAZISKAV

Emisije CO₂ nastanejo zaradi uporabe mineralnega dizelskega goriva pri vseh mehaniziranih opravilih v vinogradniški pridelavi: osnovna in dopolnilna obdelava tal, gnojenje, varstvo, strojno pobiranje pridelka in interni transport pri pridelavi. Zaradi uporabe gnojil (anorganska in organska) nastanejo dodatne emisije toplogrednih plinov, ki so preračunane na ekvivalent CO₂. Seštevek emisij iz porabe mineralnega dizelskega goriva in gnojil (mineralnih in organskih) nam da končno emisijo CO₂. Ogljični odtisi v konvencionalni pridelavi grozdja so določeni iz povprečne porabe mineralnega dizelskega goriva (poraba goriva izmerjena na kmetijah) za delovne operacije ter predvidenih količin gnojila (organskega in anorganskega) za določeni pridelek grozdja. Emisije toplogrednih plinov v primeru male kmetije znašajo 127,04 kg CO_{2ekv}/t pridelka pri ročnem pobiranju pridelka grozdja ter 131,6 kg CO_{2ekv}/t pridelka pri strojnem pobiranju pridelka grozdja. V primeru srednje velikosti kmetije emisije znašajo 118,9 kg CO_{2ekv}/t pridelka pri ročnem pobiranju pridelka grozdja ter 123,1 kg CO_{2ekv}/t pridelka pri strojnem pobiranju pridelka grozdja. Za veliko kmetijo emisije znašajo 110,8 kg CO_{2ekv}/t pridelka pri ročnem pobiranju pridelka grozdja ter 114,6 kg CO_{2ekv}/t pridelka pri strojnem pobiranju pridelka grozdja. Emisije CO_{2ekv}/t pridelka – grozdja, upadajo z velikostjo kmetije, najvišje so pri mali ter najnižje pri veliki kmetiji usmerjeni v vinogradniško pridelavo. Poleg tega so emisije CO_{2ekv}/t pridelka – grozdja nekoliko višje pri vseh treh velikostih kmetij pri mehaniziranem pobiranju pridelka grozdja v primerjavi z ročno trgatvijo grozdja.

Ogljični odtisi v integrirani pridelavi grozdja so določeni iz povprečne porabe mineralnega dizelskega goriva (poraba goriva izmerjena na kmetijah) za delovne operacije ter predvidenih količin gnojila (organskega in anorganskega) za določeni pridelek grozdja. Emisije toplogrednih plinov v primeru male kmetije znašajo 110,4 kg CO_{2ekv}/t pridelka pri ročnem pobiranju pridelka grozdja ter 120,6 kg CO_{2ekv}/t pridelka pri strojnem pobiranju pridelka grozdja. V primeru srednje velike kmetije emisije znašajo 103,9 kg CO_{2ekv}/t pridelka pri ročnem pobiranju pridelka grozdja ter 113,2 kg CO_{2ekv}/t pridelka pri strojnem pobiranju pridelka grozdja. Za veliko kmetijo emisije znašajo 97,3 kg CO_{2ekv}/t pridelka pri ročnem pobiranju pridelka grozdja ter 105,8 kg CO_{2ekv}/t pridelka pri strojnem pobiranju pridelka grozdja. Emisije CO_{2ekv}/t pridelka – grozdja upadajo z velikostjo kmetije, najvišje so pri mali ter najnižje pri veliki kmetiji usmerjeni v vinogradniško pridelavo. Poleg tega so emisije CO_{2ekv}/t pridelka – grozdja nekoliko višje pri vseh treh velikostih kmetij pri mehaniziranem pobiranju pridelka grozdja v primerjavi z ročno trgatvijo grozdja.

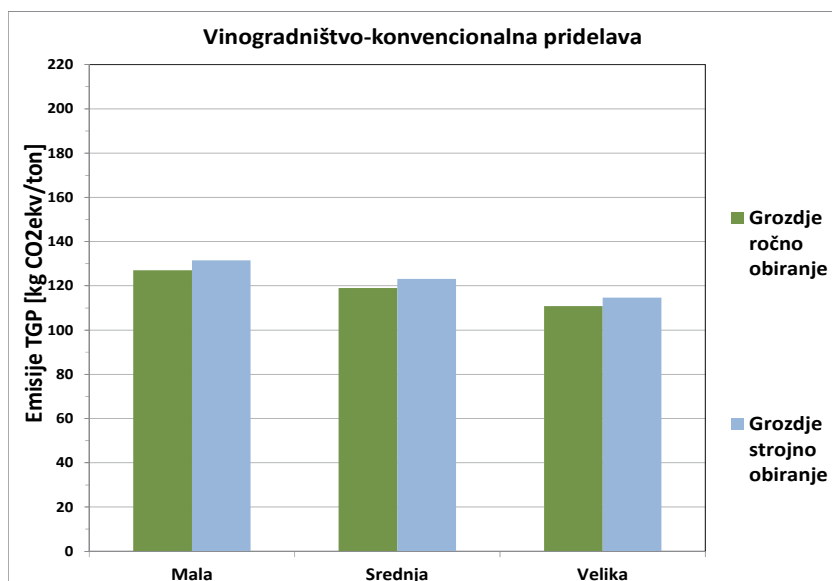


Tabela 1 Ogljični odtis določen za tri velikosti kmetij (mala, srednja, velika) v primeru konvencionalne vinogradniške pridelave

Table 1 Carbon footprint found for the three farm sizes (small, medium, large) in the case of conventional vineyard production

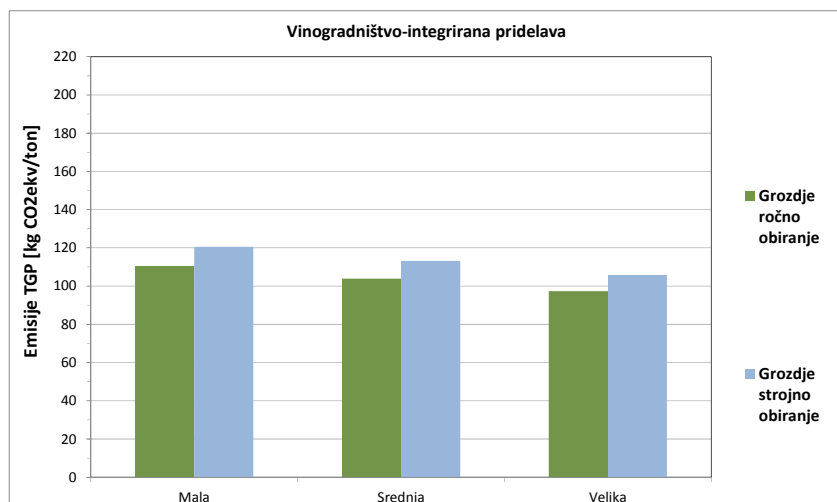


Tabela 2 Ogljični odtis določen za tri velikosti kmetij (mala, srednja, velika) v primeru integrirane vinogradniške pridelave

Table 2 Carbon footprint found for the three farm sizes (small, medium, large) in the case of integrated vineyard production

Ogljični odtisi v ekološki pridelavi grozdja so določeni iz povprečne porabe mineralnega dizelskega goriva (poraba goriva izmerjena na kmetijah) za delovne operacije ter predvidenih količin gnojila (organskega in anorganskega) za določeni pridelek grozdja. Emisije toplogrednih plinov v primeru male kmetije znašajo 182,7 kg CO_{2ekv.}/t pridelka pri ročnem pobiranju pridelka grozdja ter 196,8 kg CO_{2ekv.}/t pridelka pri strojnem pobiranju pridelka grozdja. V primeru srednje velikosti kmetije emisije znašajo 172 kg CO_{2ekv.}/t pridelka pri ročnem pobiranju pridelka grozdja ter 185 kg CO_{2ekv.}/t pridelka pri strojnem pobiranju pridelka grozdja. Za veliko kmetijo emisije znašajo 161,3 kg CO_{2ekv.}/t pridelka pri ročnem pobiranju pridelka grozdja ter 173,1 kg CO_{2ekv.}/t pridelka pri strojnem pobiranju pridelka grozdja. Emisije CO_{2ekv.}/t pridelka – grozdja upadajo z velikostjo kmetije, najvišje so pri mali ter najnižje pri veliki kmetiji usmerjeni v vinogradniško pridelavo. Poleg tega so emisije CO_{2ekv.}/t pridelka – grozdja nekoliko višje pri vseh treh velikostih kmetij pri mehaniziranem pobiranju pridelka grozdja v primerjavi z ročno trgatvijo grozdja.

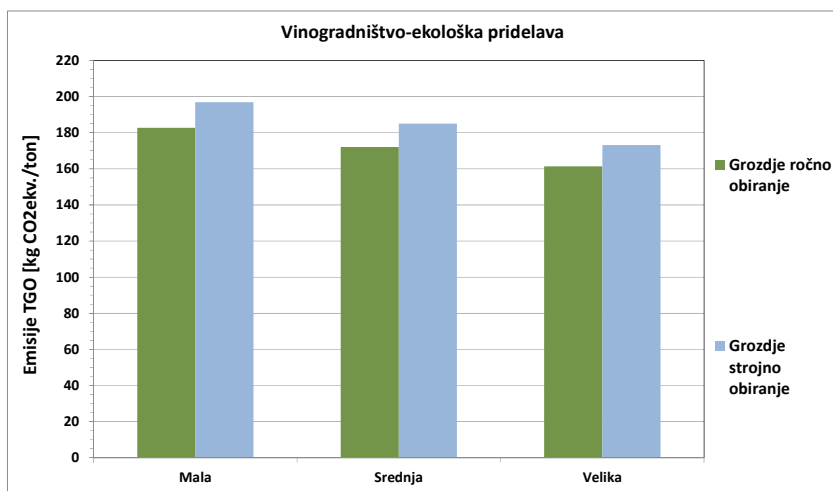


Tabela 3 Ogljični odtis določen za tri velikosti kmetij (mala, srednja, velika) v primeru ekološke vinogradniške pridelave

Table 3 Carbon footprint found for the three farm sizes (small, medium, large) in the case of organic vineyard production

Integrirana in ekološka pridelava se glede mehaniziranih delovnih postopkov najbolj razlikujeta od konvencionalne pridelave. Iz tega izhajajo tudi razlike v porabi energije med posameznimi pridelavami. Tako se v konvencionalni vinogradniški pridelavi lahko uporablja tudi dopolnilna obdelava tal, za vzdrževanje medvrstnega prostora v vinogradu pa se uporablja škropljenje s herbicidi za zatiranje plevelov in trave v vrsti. Poleg tega konvencionalna pridelava ima največje število škropljenj v primerjavi z integrirano in ekološko pridelavo. V integrirani pridelavi ni dopolnilne obdelave tal za vzdrževanje medvrstnega prostora v vinogradu (za vzdrževanje omenjenga prostora v vinogradu se

uporablja mulčenje ter škropljenje plevelov s herbicidi v vrsti). Poleg tega je število škropljenj v tej pridelavi zmanjšano v primerjavi s konvencionalno pridelavo. V ekološki pridelavi se za vzdrževanje zatravljenega prostora v vinogradu uporablja med vrstno mulčenje in košnja tal v vrsti. Mulčenje se opravlja z elisnimi ali mulčerji kladivarji, poraba dovoljenih fitofarmacevtskih sredstev (bakreni preparati) za varstvo trte je zmanjšana na 20 do 50 %, tako da je število škropljenj še nižje v primerjavi z integrirano pridelavo. Razlika je tudi pri porabi energije za gnojenje, pri konvencionalni pridelavi se uporablja gnojenje z mineralnimi gnojili. V primeru integrirane pridelave je predvidena uporaba mineralnega in hlevskega gnoja, za ekološko pridelavo pa je predvideno, da se uporablja hlevski gnoj. V ekološki pridelavi se uporabljajo organska gnojila (gnoj), ki imajo nižje emisije toplogrednih plinov v primerjavi z anorganskimi gnojili (mineralna gnojila). Poleg tega se v ekološki pridelavi lahko tudi uporablja kombinacija organskih gnojil v kombinaciji s počasi topnimi mineralnimi gnojili.

ZAKLJUČEK

Seštevek emisij CO₂, ki nastanejo zaradi uporabe fosilnega goriva in ekvivalentnih emisij CO₂ iz gnojil uporabljenih v procesu pridelave, da končno emisijo vinogradniške pridelave. Emisije CO_{2ekv}/t pridelka – grozdja, so najnižje pri integrirani, višje pri konvencionalni ter najvišje pri ekološki vinogradniški pridelavi. Vzrok za najvišje emisije CO_{2ekv}/t pridelka – grozdja v ekološki pridelavi je v nekoliko višji porabi mineralnega dizelskega goriva ter da so pridelki v ekološki pridelavi nižji, tako da izračun CO_{2ekv}/t pridelka – grozdja da posledično višje emisije. Emisije CO_{2ekv}/t pridelka – grozdja, upadajo z velikostjo kmetije, najvišje so pri mali ter najnižje pri veliki kmetiji usmerjeni v vinogradniško pridelavo. Emisije so pri mali kmetiji višje zaradi uporabe traktorskih agregatov manjše moči, ki so energetsko manj učinkoviti v primerjavi s traktorskimi agregati večje moči, poleg tega je več praznih hodov pri strojnih opravilih na majhnih delovnih površinah. Emisije CO₂ so tudi nekoliko višje pri vseh treh velikostih kmetij pri mehaniziranem pobiranju pridelka grozdja v primerjavi z ročno trgatvijo grozdja.

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CARBON FOOTPRINT OF VINEYARD PRODUCTION

ABSTRACT

Carbon footprint of mechanized vineyard production in Slovenia was determined. An analysis of the carbon footprint in the case of conventional, integrated and organic vineyard production for the three sizes of vineyard farms was made. In all mechanized working operations in vineyard production, energy of mineral diesel fuel is used to power tractors with connected machines, or in the case of mechanical harvesting of the grapes with self-propelled machines - harvesters for grapes. For the carbon footprint analysis CO₂ emissions from the consumption of mineral diesel fuel for powering farm machinery (direct energy consumed in the process of production in vineyards) were used. In addition to the CO₂ emissions from the mineral diesel fuel used in the vineyard production, also were covered greenhouse gas emissions resulting from the use of organic and mineral fertilizers in the production and converted to equivalent CO₂. In the case of conventional production in vineyards, provided is use of mineral fertilizers, in integrated vineyard production combination of mineral and organic fertilizers and in organic vineyard production only usage of organic fertilizers. The sum of CO₂ emissions resulting from mineral diesel fuel and CO₂ equivalent emissions from fertilizers used in the vineyard production process, results in the final emissions of CO_{2equ}/t crop - grapes vineyard production. It has been found that emissions of CO_{2equ} /t crop - grapes, are the lowest in integrated, higher in conventional and highest in the organic vineyard production.

Key words: *the carbon footprint of vineyard production, direct energy consumption, emissions from mineral diesel fuel, emissions from fertilizers, emissions of CO_{2equ}/t crop - grapes, CO₂ emissions in conventional, integrated and organic vineyard production*



CRITICAL ANALYSIS OF THE REFLECTION BY THE RESOURCES QUALITY AGRO-LIVESTOCK IN THE LABELING OF GENERATED FOODSTUFF

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SUMMARY

Nutritional labeling of food products is an important goal for ensuring the operation of a free market in both the European and adjacent area. The paper points out some limitations of European legal provisions in connection with the legislation of the countries geographically located in the Black Sea area. It is reflected by concrete examples and analyzes about the quality of agro-livestock as resources underlying healthy food. It is shown some proposals and recommendations for to improve some modalities for to highlight the role of traceability in the food product profile.

Keys words: *Nutritional labeling, agro-livestock, quality, laws, food*

INTRODUCTION

The steps of the historical evolution of human civilizations are often presented in direct connection with the structures and forms of nourishment. The nutrition is the process by which the human body takes nutrients from environment that turns to secure the normal metabolic processes. Given the complexity of the nutrition it is needed a systemic approach. Throughout time it have revealed the factors which determined the food habits, food traditions, the evolution of the concept of food (transition from art to science) and especia-

lly agro-food problem, that are interconnected with other global issues (energy, environment) [10]. With the raising of the education and culture of the people it is changed the food choices. From the primitive man concern to procure food for to survive, it came to the multiple scientific approaches to human consumption, with the course of action, especially geared towards food consumption according to the desire of the right man at the right time. The daily food consumption should be directly correlated with the particular condition of the body, on both: age and health characteristics of the individual. [2]

The nutrition problem concerns increasingly more the global population, manifesting learning and understanding in environments need more broad general principles of food science, the necessary nutrients for the body, food groups and their share in rational nutrition sources pollution of food, aiding the risks assumed by eating the wrong foods. The population is fed from the market, based on the information read on the food labels [4], [6], [13]. The ability to track freshness data in transit and storage of food products through indicator labeling can be useful in reducing potential food hazards from reaching consumers [10].

For a better producer-consumer communication is deemed necessary to critically analyze of the food labels of trade, especially in relation with the providing more accurate information about the natural origin, from the primary agroalimnetar fund. At the same time the critical analysis targeting the insofar as it complies with current EU directives on food labeling, with details about the traceability. [2], [14]

METHODS

This critical analysis of the labels was performed within the research contained in NUTRILAB project (2012- PEOPLE- FP7- IRSES, 318,946 - NUTRILAB, Nutritional Labeling Study in Black Sea Region Countries project), where it is confirmed a lot of existences of negligence in the labels of the foodstuff by some manufacturers and many problems of the joint knowledge and understanding of nutrition labeling messages by the consumers. [14]

It were analyzed over 786 labels of foods which are in the markets from the countries nearly the Black Sea, especially from Bulgaria, Moldova Republic, Romania, Russian Federation and Ukraine. It was tracked the compliance with the directive 2000/13 / EC, which gives to the consumers the opportunity to obtain on the food label all essential information concerning the composition, manufacturer, methods of storage and preparation, the existence of the content of substances known as allergens and other things that can harm the consumer and so on. In accordance with European Regulation (EC) No 1924/2006, these foodstuffs could be accepted in the markets if the information from the labels could be well understood by the average consumer. [1], [2], [14]

For consumer consultation was launched and a questionnaire in these five countries, which is also in the online version on web-site www.nutrilabproject.eu. [14].

The labels were collected from different commercial areas from these 5 countries, between May 2013 and September 2014. The labels were selected from different categories of foods. The data are registered in Table 1.

Table 1 Data extracted from the analyzed labels

Country		Bulgaria	Rep. Moldova	Romania	Russian Federation	Ukraine	TOTAL
Labels	<i>No</i>	134	127	184	168	173	786
from which:	%	17,05	16,16	23,41	21,37	22,01	
labels with details about manufacturer	<i>No</i>	108	92	162	126	122	610
	%	80,60	72,44	88,04	75,00	70,52	77,61
labels with details about resources	<i>No</i>	46	36	76	57	50	265
quality agro- livestock	%	34,33	28,35	41,30	33,93	28,91	33,71

The comparative situation can be seen also in the graphs of the figure 1.

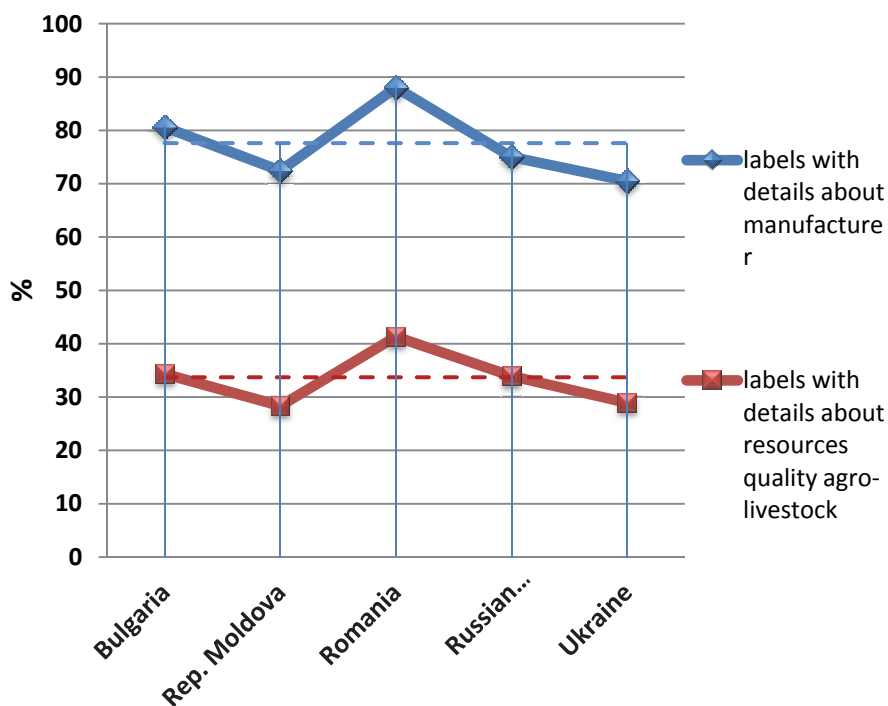


Figure 1- Graph with a comparative situation on countries about labels analyzed.

The labels were studied by mixed teams of specialists, aiming at several aspects about the extent to which there is compliance with European rules and with laws into force, existing in the country where that are on the market, and also about the compliance of the principles of nutritional labeling. [14].

RESULTS AND DISCUSSION

After critical analysis of samples collected from the labels from these 5 countries is noted an aspect of transition to an optimum system, more accurate better for the consumers with enough information on the structural characteristics and about the quality of food purchased. In countries such as Ukraine, Moldova and Russia is still a more lenient legislation for domestic markets, but are not good for international rules, are unaligned at EU regulations about the movement of food, so many autochthonous manufactories still producing not mentions the complete data on the labels. Even food markets from Bulgaria and Romania, there are still manufacturers, especially for domestic (below 20%) that do not provide complete data.

The deeper problem is the lack of details about the origin of food, only 33.71 % (average) manufactories mentioning the cases data quality about the raw materials of agro-livestock.

The identification through labels the origin of feed and food ingredients and food sources are of prime importance for the protection of consumers. Therefore the Regulation EC/178/2002 defines traceability as the ability to trace and follow food, feed, and ingredients through all stages of production, processing and distribution. The Regulation contains general provisions for traceability (applicable from 1 January 2005) which cover all food and feed, all food and feed business operators, without prejudice to existing legislation on specific sectors such as beef, fish, GMOs etc. [1], [8] [10] [11] [14]

Although over 70% of the labels have mentioned most features on the principles of nutritional labeling of food, and the product's country of origin, these have not said enough details about harvest characteristics of the plant, or about animal healthy wich are at the origin of the foodstuffs. (Figure 2)



Figure 2 The reflection of the resources quality agro-livestock in the labeling of generated foodstuff.

After some discussions with some food producers it is known that benefit some data about the raw materials purchased, but keeps them in institutions without put these on the labels for to inform the consumers. These data are available to authorized institutions with food control, just in cases when it is found defective or unpleasant effects on consumers of finished products. (methoxy-food infections or other illnesses). This aspect considerably reduces food safety.

The traceability facilitates the withdrawal of foods and enables consumers to be provided with targeted and accurate information concerning implicated products. The establishing of the security in the food chain is the goal of many EU regulations, but how companies achieve that goal is largely up to them. [2], [4] [5] [6] [13]

When placing a product on the market, the operator must transmit the following information in writing to the operator receiving the product an indication of each food ingredient produced from GMOs and an indication of each raw material or additive for feeding stuffs produced from GMOs.; If there is no list of ingredients, the product must bear an indication that it is produced from GMOs. [1], [7] [12]

Paradoxically, on the labels of some traditional products, prepared by family associations are given useful details about the history of foodstuff, even some therapeutically indications, but lacks details about the nutritional value, the presence in food of ingredients or validity terms and so on.

CONCLUSIONS

Now, there are many technical solutions for product ID systems. They include bar coding and imprinting tools that use tracking numbers to link finished products back to specific data relating to their production history. [13], [8]

It is necessary to make a combination between the traceability principle and the labeling therefore for to obtain more than a tracking and recovery tool, including some tools such as environmental monitors and product scanners that link information back to sophisticated data storage systems, which gather and organize product data so that it can be easily retrieved for safety, security and quality assurance reviews or recall situations. [1], [3] [9]

Were found on all markets studied some food products manufactured by companies of international prestige, proving clearly the effects of globalization, but these products have an attractive packaging and labeling, with complete information to consumers, in accordance with all EU rules imposed. For a correct and healthy eating it must to educate the consumers in the sense of understanding and properties of the messages transmitted by labeling.

It is need a global process optimized, with more complex actions for aligning the legal provisions, same in all the countries, related to consumer communication of all details about the food.

It is also necessary a better protection for the clean and healthy food.

ACKNOWLEDGEMENT

The study was performed in an international mobility supported by FP7-PEOPLE-2012-IRSES, 318946 – NUTRILAB, NUTritional LABeling Study in Black Sea Region Countries project.

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